Diseases of the Knee

Management in Medicine and Surgery

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455 Illustrations

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This book is dedicated to
my mother and father
whose stature rises to higher levels as
I become older They are blessed with
the faculty of giving so much and
asking for so little

Preface

The literature contains numerous articles dealing with the anatomy, the mechanics and the disorders of the knee joint Much of this material is still controversial, and in spite of the fact that some of the investigations were conducted many decades ago, the last word on many of the subjects provoking disagreement has not as yet been recorded Contributions of great profundity have been made by John Goodsir, Love, Sir Robert Jones, MacKenzie, G T Fisher, Walmsley, Herzmark, Annandale and Nicoll, more recently much has been added to our knowledge by Ivar Palmer, King Bohler, Helfet, D M Bosworth, Brantigan and Voshell, Bennett Waine and Bauer, Cubins and his co-workers, Hey Groves, Gallie and Le Mesurier, Smillie, O'Donoghue and a host of others The desire to confirm or refute the observations recorded by some of the aforementioned workers has been the stimulus to the undertaking of the investigations which are contained in this work

The study on the comparative anatomy of the knee joint reveals the alterations that have occurred in man Of interest is the reduction in size of the cruciate ligaments as compared with those encountered in lower primates such as the macacque and the chimpanzee in which the knee joints are capable of wide arcs of rotary motion Nevertheless, the role of the cruciates in the functional mechanics of the knee joint in man must not be underestimated, making it imperative that whenever possible the integrity of these structures, if disrupted should be restored In order to meet the requisites of the erect posture, certain changes have occurred in the configuration of the femoral condyles the lateral condyle is larger than the medial and supports the greater portion of the body weight in the upright position

Many surgeons fail to understand the significant role that the patella plays in enhancing the power of the quadriceps apparatus, which is the most important single stabilizer of the knee joint This is reflected in the numerous patellectomies that are performed indiscriminately Study of the comparative anatomy and the embryology of the knee joint discloses that the patella is not a sesamoid bone in response to functional stimuli, as so many believe, it not only affords protection to the anterior aspect of the knee joint but it also increases the mechanical efficiency of the extensor apparatus In man, in whom the mechanical efficiency of the knee joint surpasses that of all lower forms, the patella is massive and is endowed with a wide range of motion The clinical observations of the author support the above observations, therefore, he makes a plea that this important component of the knee joint be spared whenever it is possible

Throughout this book, the importance of a normal quadriceps muscle in order that the knee may perform efficiently and without harmful stresses and strains to its synovialis, capsule and ligaments, is emphasized repeatedly Failure to recognize this established fact has led to irreversible pathologic alterations in the joint which are responsible for profound dysfunction The responsibility of the surgeon does not terminate with treatment of a local lesion or with the execution of a skillfully performed operation on the knee joint It is his moral obligation to prescribe and supervise a postoperative regimen designed to restore normal quadriceps power and complete rehabilitation of the patient, only then does his responsibility end

During World War II the author had the good fortune to be assigned to a center which was actively engaged in the basic training of

many thousands of Marines Traumatic lesions of the menisci, the ligaments and the extensor apparatus occurred frequently during the rigorous training These cases together with the many cases encountered in civilian life resulting from injuries on football and baseball fields and the basketball court, provided the author with an abundance of clinical material In addition for a period of 22 months the author had the opportunity to treat hundreds of fresh casualties some of which were seen almost immediately after the injury had occurred This tour of duty provided many cases of soft tissue injuries about the knee open and penetrating wounds of the knee joint and all types of fractures of the bony elements of the knee joint. Finally, the author s association with a military rehabilitation center during the last few months of the war and also after the termination of hostilities provided ample opportunities to study the many problems of restoration of an injured knee joint to normalcy

In the section dealing with surgical approaches and procedures every effort has been made to depict clearly by drawings and description the pertinent surgical anatomy of the region in question For the sake of completeness some operative procedures have been included which the author rarely or never employs however emphasis has been laid on those procedures which have proved to give the most satisfactory long term end results

In order to create a work which includes all the material deemed essential it has been necessary to draw from many sources Particular care has been taken to give full credit to the source of the material used If there are omissions they have been unintentional and the author wishes to record his apologies and regrets

It is the hope of the author that the information contained herein will be of value not only to the orthopaedic expert but also to the general surgeon the general practitioner and the student Considerable stress has been laid on the more common pathologic condition of the knee joint particularly traumatic lesions of the menisci the ligaments the extensor apparatus and loose bodies in the knee joint villous synovitis and hypertrophic arthritis The pertinent clinical manifestations which will lead to a correct diagnosis have been emphasized and the preferred method of treatment has been described in detail Further it is hoped the investigations recorded herein will provide the reader with a broader understanding of the mechanism and the pathogenesis of the lesions discussed and will augment his diagnostic faculties and will promote effective means of therapy designed to result in complete rehabilitation of the patient Finally it is the author's wish that this book may be a stimulus to the young minds of our profession to investigate further the many controversial topics

This work could not have been undertaken without the co-operation of Dr G A Bennett Director of the Department of Anatomy and Dean of the Jefferson Medical College who made available to the author several hundred knee joints obtained from cadavers These specimens were dissected carefully and the normal anatomy was studied and recorded in Chapter 4 For this and many other acts of kindness and for his guidance and encouragement, I wish to record a debt of gratitude to Dr Bennett A debt of thanks is due to Dr Paul C Swenson Professor of Radiology Jefferson Medical College who unselfishly permitted me to use all the facilities that belong to his department.

The author also owes a debt of thanks to Dr J Dowling Dr I Smith Dr P Roma now Dr M Wohl Dr H Snedden Dr T Forker and Dr F Mattei all of whom assisted faithfully in the investigative studies done on the mechanics of the knee joint to Dr G Deibert who helped collect and classify many specimens obtained following meniscectomies to Mrs M M Del B Sittel for her conscientious work on the numerous

drafts of the manuscript to Miss V Quick who helped collect the many case histories and prepared and arranged the illustrations used in this work to Mr C. Brill the artist whose enthusiasm is reflected in all the drawings, to Mr A. Hancock, the photog rapher, for his untiring interest and pains taking work, and lastly to the J B Lippin cott Company for their constant encourage ment instructive criticism and loyalty

A F DePalma

Contents

EVOLUTION OF THE PELVIC GIRDLE

Evolution of the pelvic girdle lagged behind the evolution of the pectoral girdle The elasmobranches confirm this point the pectoral girdle of the elasmobranches discloses a well-developed dorsal arm (the scapula) whereas the pelvic girdle reveals only little indication of a dorsal arm (the ilium) However in the elasmobranches both the pectoral and the pelvic extremities are jointed to their respective girdles by a ball and socket articulation Although the pelvic and the pectoral appendages have many features in common and retain their basic similarity to one another the evolution of the lower limb differs from that of the upper limb In the early stages of evolution the pelvic girdle developed as a link between the fin skeleton and the body wall but was free of the axial skeleton later it fused with the vertebral column Its position in relation to the body wall brings it in close association with the cloacal aperture, where as the pectoral girdle is in close proximity to the gills series

Fishes

In primitive fishes the pelvic girdle comprised an extension of the fin skeleton into the body wall This arrangement provided

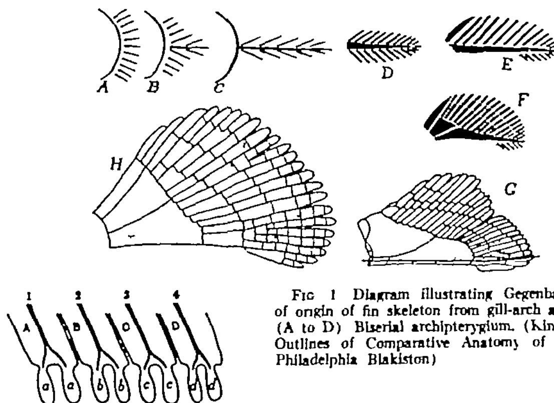


Fig 1 Diagram illustrating Gegenbaur's theory of origin of fin skeleton from gill-arch and gill rays (A to D) Biserial archipterygium. (Kingsley J S Outlines of Comparative Anatomy of Vertebrates, Philadelphia Blakiston)

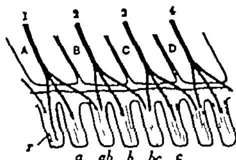


Fig 2 Formation of adult radial muscles from embryonic muscle buds and their motor nerve supply (*Above*) Embryonic stage with a pair of buds to each segment. (*Below*) Adult stage with radial muscles compounded of material from adjacent buds 1 to 4 4 spinal nerves A to D 4 myomeres a to d muscle buds r radial muscles. (Goodrich E S Studies on the Structure and Development of Vertebrates London Macmillan)

Fig 3 Hypothetical evolution of paired fins and their skeletal supports (A) Primitive stage, characterized by continuous fin folds The dorsal and the ventral fins posterior to the anus are median and unpaired (B) Elasmobranch stage. Paired fin folds persist only in the region of the pectoral and the pelvic fins, median fins have become discontinuous. (C E) Hypothetical stages in the evolution of the skeleton of the pelvic fins of elasmobranch fishes The right side of C and E represents a later stage in the phylogenesis than the left. E represents the differentiated skeletons of the girdle and the extremity (after Wiedersheim) (Neal and Rand Chordate Anatomy Philadelphia, Blakiston)

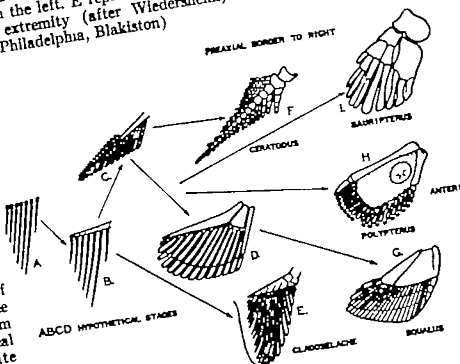
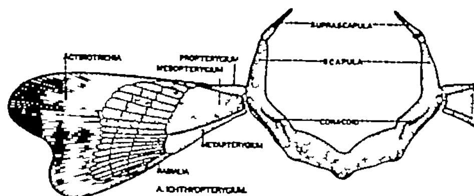


Fig 4 Diagrams illustrating hypothetical evolution of the extremities of diapnoan (I), ganoid (H) and elasmobranch (G) from a fin fold supported by a series of similar radial cartilages. By fusion of radial cartilages basilia (basal cartilages) are formed. Skeletal supports of the fins eventually differ in relation of the basal elements to the radialia (Redrawn from A. Brazier Howell) (Neal and Rand Chordate Anatomy, Philadelphia Blakiston)



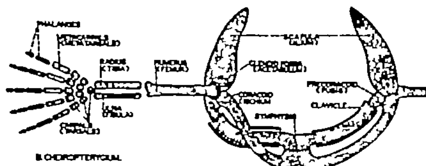


Fig 5 Diagrams illustrating scheme of pectoral appendages of lower and higher vertebrates. (*Bottom*) Names of corresponding parts of pelvic appendages are shown in parentheses. (Neal and Rand Chordate Anatomy, Philadelphia Blakiston)

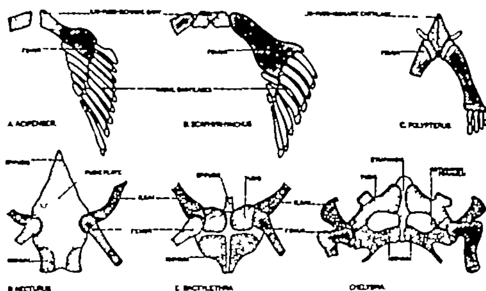


Fig 6 A series of 6 appendicular skeletons illustrating the gradual emergence of the elements of the pelvic girdle found in reptiles and mammals. They represent fairly well the stages in the evolution of the human pelvis First come the separation of girdle and extremity (A and B) then the fusion of the paired elements of the girdle into a median ventral cartilaginous plate (C and D) differentiation of bony ischium pubis and ilium (D and F) and finally the appearance of the obturator foramen (F) There is no essential difference between the girdles of reptiles and mammals. (Redrawn from Wilder History of the Human Body New York Holt)

support for the fin and attachment for its muscles Further in the scale of evolution the paired ventral cartilages of the pelvic girdle fused in the mid line, forming a transverse plate in front of the cloacal outlet as seen in Selachii The fin skeleton is attached to the outer border of the transverse plate, which is pierced by diazonal nerves A slight dorsal process is noted above the articulation of the fin. Some consider this elevation the forerunner of the ilium of tetrapods Still further in the evolutionary scale the originally cartilaginous pelvic girdles may become ossified and remain as two separate bones lying in the body wall and meeting in front of the anus Such an arrangement is observed in the teleostomes

Amphibia

Although the beginning of the pelvis is mostly conjectural, evidence points to the possibility that it was initiated by a sagittal bar of cartilaginous tissue in the mid line associated with function of muscles controlling the cloaca Later this bar developed into a ventral plate (ischiopubic bar) and was concerned exclusively with ventral muscles No ilium was present in the early stages of evolution, the femur articulated with the dorsal aspect of the ischiopubic bar Further in the evolutionary stage a dorsal process developed which projected into the dorsal musculature, providing attachment for muscles of the back and the tail.

In the most primitive amphibia (Stegocephalia) the ventral segment of the girdle is broad with a large ischium and a smaller pubis the ilium is almost vertical tapering dorsally and articulates with one sacral rib The pubis provides a foramen for the obturator nerve Later, centers of ossification appeared in the ventral plate, these centers correspond to the ischium and the pubis of reptiles (Fig 6)

Study of fossil remains suggests that the terrestrial amphibians and the primitive reptiles possessed hind limbs which held the lower legs in a transverse plane with the knee and the foot directed laterally Living lizards and urodeles possess knees which are directly lateral, but their lower legs point posteriorly (Howell)

Reptiles

The basic pattern of pelvic girdles of the reptiles closely resembles that of the amphibia The ischium and the pubis comprise the ventral plate, the latter provides an opening for the obturator nerve. Generally, the ilium is a stout bone and articulates with two sacral vertebrae At first the ilium occupied a vertical plane, later, because of postural influences and functional demands of the lower extremity, a caudal process was developed for attachment of back muscles However, when the laterally directed knee and foot were brought beneath the body, new functional demands were made upon the ilium, which responded by developing a cranial process to provide a more anterior attachment for iliac muscles, while its caudal process diminished The ischium and the pubis responded to the same influences that effected the change in the inclination of the ilium Both of these migrated to a dorsocaudal position to provide a better retractive angle for the vertical femur (Howell)

Mammals

Despite the lack of evidence based on fossil remains linking the evolution of the pelvic girdle of the mammals to that of the therapsid reptiles the basic pattern of the mammalian girdle is similar to that of the primitive reptilian girdle The ilium is directed forward and the symphysis is shortened particularly in Insectivora the ischium is extended dorsally and is directed caudally, and the acetabulum has migrated posteriorly to the sacrum Generally the ilium the ischium and the pubis radiate from the acetabulum. A well formed obturator foramen is present In monotremes

and marsupials epipubic bones developed which articulated with the pubis these are considered by some workers as homologous with the lateral pubic processes of Amphibia.

In mammals there is an increase in the number of sacral vertebrae which articulate with the ilium. In man 3 of the 5 sacral segments articulate with the coxal bone Man s change from a quadruped to a biped was responsible for the acquisition of certain features peculiar to the human pelvis The craniocaudal dimensions have decreased the lateral dimensions have increased, thereby broadening the pelvis, and the ilium has expanded dorsally The shortening and the broadening of the ilium are undoubtedly in response to the new function of the gluteus medius muscle and to provide attachment for the abdominal muscles in the upright posture In addition to the aforementioned adaptive changes the ischium and the pubis have shifted dorsally this was necessary to meet the new functional demands of the musculature of the thigh in the erect position which deleted the angle of leverage of the hamstring muscles

EVOLUTION OF THE LOWER EXTREMITIES

Considerable controversy still exists among students of vertebrate morphology relative to the derivation of the cheiropterygium or the tetrapod limb (also called the pentadactyl limb) from the icthyopterygia (paired fins of fishes) It is interesting to note that in spite of the wide differences between the fore and the hind limbs sufficient evidence has been accumulated to suggest that they were similar in primitive vertebra and that they evolved from the same basic pattern In the evolutionary stages of the free paired appendages the proximal or the basal ends of the radials (cartilage rays) fused to form basilia. With the demand of greater movability of the fin a joint evolved between the radials and the basilia, several of which in turn articulated with the girdle Such a pattern is demonstrable in the paired fins of the elasmo-branches, which possess three basilia (propterygium, mesopterygium and metapterygium) situated between the girdle and the radials of the fin (Fig 5) The pectoral girdles and the fins of the crossopterygii the Eusthenopteron and the Sauripterus (fossils from upper Devonian) provide an arrangement of skeletal elements which may be considered as a link between paired fins of fishes and tetrapod limbs These two genera of crossopterygian fishes are accepted as close to the forms from which the amphibia evolved Essentially the basic scheme of their pectoral appendages consisted of a proximal segment which joined to two middle segments which in turn articulated with several distal elements From the proximal element evolved the humerus from the middle elements the radius and the ulna and from the distal ones the carpus and the digits Although these crossopterygii provide a link between the paired pectoral fins of fishes and the pectoral limbs of the tetrapod nothing is known of the pelvic fins of these fishes. Nevertheless it is logical to assume that the fishlike forerunners of the tetrapods possessed pectoral and pelvic fins having a similar basic pattern and from these evolved the pentadactyl limb

In the pelvic appendage the evolution was as in the pectoral limb Pronounced changes occurred in the skeletal elements when animals emerged from the water and adopted a terrestrial existence Both the pectoral and the pelvic limbs were then used for locomotion and support In the amphibia the first animals to adopt terrestrial habits the pentadactyl limb evolved from the paired fins. From the distal elements of the pelvic fin arose the tarsus the metatarsus and the phalanges from the middle elements the tibia and the fibula and from the proximal element the femur

Femur

The characteristic features of the femur of the primitive amphibia are less known

than those of the humerus However, the primitive amphibian femur resembled in a large measure the femur of the early reptiles. Its length was greater, and its diameter was less than the corresponding humerus, but it did not possess the tetrahedral configuration of the humerus. It appears that changes in posture of the lower extremity are reflected in the relation of the articular surface of the head of the femur to the shaft Early tetrapods possessed an ovoid articular surface at the proximal end of the shaft of the femur while in some reptiles and monotremes the articular surface tended to incline toward the lateral side of the shaft. These features are consistent with an extremity in which the knee is held at a higher level than the acetabulum, and the arcs of movements of the thigh are confined to the horizontal plane This is in contrast with the observations noted in mammal like reptiles and dinosaurs in which the articular surface of the head of the femur had migrated to the medial side of the shaft such a feature points to a thigh assuming a more nearly vertical position

Reptiles do not possess a femoral neck comparable with that found in mammals. In mammals a subspheroidal femoral head and a well-defined, constricted neck are constant and characteristic features the articular surface being more nearly spherical than that of the corresponding humerus Howell points out that the greater mobility of the forelimb may play a part in the differences in shape and size of the humeral and the femoral heads He notes "If so then the reason for the extent of the articular surface is probably that the acetabulum is immovable while the position of the glenoid may be altered"

Morphologists have encountered great difficulty in establishing the homology of the trochanters of the femur The recorded factors responsible for this difficulty are

1 Migration of many of the implicated muscles from their primitive position

2 Difficulty in homologizing the muscles of reptiles with those of mammals This has led to many errors

3 In one class the insertion of a muscle mass is associated with a tuberosity, while in another class no process is discernible Pronounced variation is demonstrable in the arrangement of the trochanters, particularly in the different reptiles these variations are the result of the same muscles or muscle mass having different angles of leverage in the different classes of reptiles

In reptiles such as the iguana, the large trochanter is situated on the medial aspect of the femoral shaft It provides insertion for the tibial-obturator muscle mass (flexor puboischiofemoralis) which corresponds to the gemelli, the obturator internus and the quadratus femoris of mammals and for a part of the short prozonal extensors which is the homologue of the psoas major muscle At the base of the trochanter the iliofemoralis (deep gluteals) inserts It becomes apparent that the greater trochanter on the medial aspect of the femur of the reptiles is the homologue of the greater trochanter of the mammals which is situated on the lateral aspect The external trochanter is either missing or poorly developed when present in the reptiles It affords an insertion to the extensor puboischiofemoralis (iliacus muscle) and is comparable with the lesser trochanter of the mammals

In mammals the large trochanter occupies a lateral position on the proximal end of the shaft of the femur Upon it insert the deep gluteal muscles (iliofemoralis group) and into its base insert the muscles of the short tibial-obturator sheet the gemelli the obturator internus and the quadratus femoris It is of interest that in some mammals such as Insectivora and some Rodentia a third process is discernible distal to the base of the large trochanter or the process may take the form of a bony crest It affords insertion for the superficial gluteus muscles In some mammals no third process is present In some of these forms of mammals the superficial gluteus muscle continues together with the biceps femoris

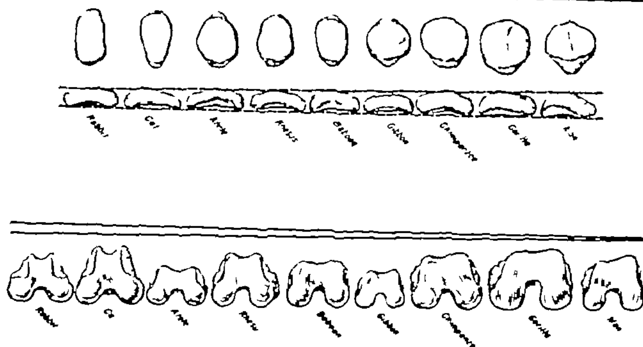


Fig 7 Note the variations in the patellar grooves of the different forms In the lower primates (ateles rhesus etc.) the grooves are well defined deep and long extending proximally on the femoral shaft in the chimpanzee the depth is markedly reduced and in man the groove is relatively well defined in the condylar region but beyond this point it is flat, and its margins are poorly defined The femoral condyles are equal in size and of the same configuration in the lower forms in the higher forms the lateral femoral condyle is more prominent reaching its greatest development in man.

muscle to the lower leg The lesser trochanter of mammals occupies a lateral position and provides an insertion for the psoas major and the iliacus muscles

A fourth trochanter is demonstrable in Crocodilia and in some birds it is situated distal to the large lateral trochanter and the caudofemoralis inserts into it It appears to be associated with a bipedal or a partly bipedal posture When present in mammals *it corresponds* to the adductor tubercle which is situated on the medial aspect of the femur proximal to the epicondyle and provides insertion for the adductor magnus in man

The relation of the greater trochanter to *the level of the head* of the femur is of some significance In general a high greater trochanter is indicative of powerful and highly specialized deep gluteal muscles as noted in runners and leapers but it is also demonstrable in other mammals for different purposes In ungulates it is high In the chimpanzee it is equal to the height of the femoral head It is higher in the gorilla and lower in man

During the evolutionary stages posture and functional requirements of the lower extremities were responsible for the rearrangement of the bony elements comprising the knee and the ankle joints In mammals which require strong extensors of the lower leg as graviportal and cursorial forms the patellar groove is well defined and is located at a distance from the condyles of the femur Moreover the patella in the aforementioned mammals is well developed and occupies a position favoring high efficiency of the extensor apparatus of the knee joint (Fig 7)

Tibia and Fibula

According to Williston *there is reason to* believe that in the amphibians and the terrestrial reptiles the proximal end of the

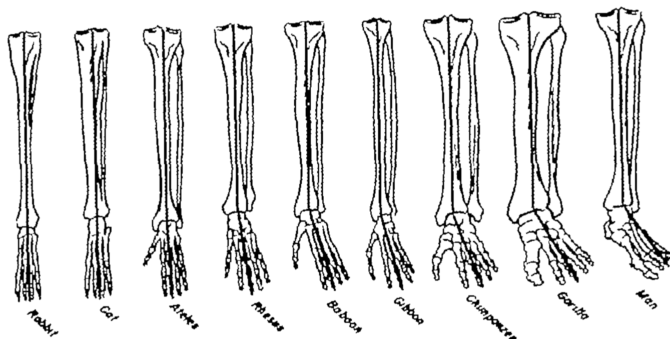


Fig 8 Note that the torsion angle of the tibia in primates, except man, is minus (the knees are directed out and the toes forward) In cursorial animals the angle approaches zero, in man the angle is expressed in positive degrees (the knees point forward while the toes point outward)

tibia bore most of the body weight, which was transmitted through the fibula to the ankle joint In these forms the tibia was larger than the fibula and articulated proximally with both the preaxial and the postaxial condyles of the femur and distally with the astragalus only On the other hand, the fibula articulated proximally only with the postaxial condyle and distally with the astragalus and the calcaneus During the evolution of the reptiles to higher forms, particularly in the biped forms, the greater weight of the body was transferred gradually to the ankle joint through the tibia This tendency reaches completion in the mammals. In these animals the tibia solely is responsible for transmitting the weight of the body to the ankle joint through the astragalus.

Posture and function are also responsible for varying degrees of torsion of the tibia The tibial torsion angle is formed by the long axis of the proximal and the distal joint surfaces In most quadrupedal mammals and primates exclusive of man the knee points in varying degrees outward whereas the toes point forward or inward This produces an inward rotation of the tibia expressed in minus degrees Cursorial and saltatorial mammals possess lower extremities which function in one plane in these the torsion angle approaches zero The torsion angle in man is expressed in positive degrees because the knee points forward while the toes point outward (Fig 8) This arrangement is an expression of recent adaptive alterations associated with acquisition of an upright posture.

In all mammals except monotremes and some marsupials, the fibula fails to articulate with the femur, and except in the artrodactyls and the elephants it does not participate in the transmission of body weight to the ankle Not infrequently the proximal part of the fibula is lacking whereas the distal part is discernible in all forms In general the distal part forms the lateral malleolus and articulates with the astragalus the exception to this is found in the monotremes in which no malleoli are present Morphologic alterations in the fibula indicate that its reduction is associated with restriction of the arcs of movements of the extremity to a single plane

2

Comparative Anatomy of the Knee Joint

In man the knee joint has evolved into a highly specialized organ surpassing in complexity the knee joint of all other animals This has been the result of added functional demands made on the knee joints when man assumed the erect position with the knee extended completely To meet these new requirements many alterations were necessary in the bony elements and the soft tissue structures comprising this articulation A study of this mechanism as it is observed in the successive stages of phylogenetic development from the simplest vertebrate animals to man discloses the numerous and intricate evolutionary changes that have occurred Such a study was made and the observations noted follow they substantiate the work of Herzmark (1938)

AMPHIBIA

Salamander

In this classification the salamander and the frog possess the simplest forms of knee joints *that of the frog is more advanced* than that of the salamander Salamanders have long slender tapering bodies their limbs are short thin delicate and very simple in structure The hind limbs are directed laterally and slightly backward The knee joints are habitually held higher than the hip joints and function in the coronal plane These animals are not capable of rapid activity Their knee joints reveal an architecture exceedingly simple the femur ends in two round condyles which articulate with the plateau of the tibiofibula. In this animal the tibia and the fibula do not exist as separate bones but are fused together to form a single structure (tibiofibula) The articular surfaces are enclosed in a thin enveloping membrane stretching from the upper borders of the femoral condyles to the lower margins of the articulating surface of the tibiofibula It is reasonable to conceive that the inner surface of this interarticular membrane may function as a synovial lining The muscles comprising the extensor apparatus converge toward the knee joint and terminate in a conjoined tendon which spans the superior surface of the articulation and inserts into the anterior aspect of the tibiofibula The patella is wanting no menisci or cruciate ligaments are demonstrable

The knee joint of the frog discloses the same simple architecture as that of the salamander Its femur terminates in a rounded bulblike articular surface with poorly defined condyles which articulate with the tibiofibula. A thin delicate interarticular membrane encloses the articular ends of the femur and the tibiofibula thereby providing *a simple joint capsule it is reinforced* through longitudinal thickenings which are all situated on the anterior aspect of the interarticular membrane and tend to converge toward the center of the anterior surface of the tibiofibula (Fig 9) No horizontal thickenings were noted Some workers are of the opinion that such thickenings in the interarticular membrane are indicative of the earliest morphologic alterations which will lead to the development of menisci observed in animals higher in the scale of development However there is no convincing evidence supporting this premise The extensor apparatus is well developed and ends in a sturdy

tendon which crosses the knee joint and inserts into the anterior aspect of the upper end of the tibiofibula It was interesting to note in this animal the pronounced development of the gastrocnemius muscle, which is a powerful flexor of the knee joint and an antagonist of the extensor muscles As in the salamander no menisci cruciate liga

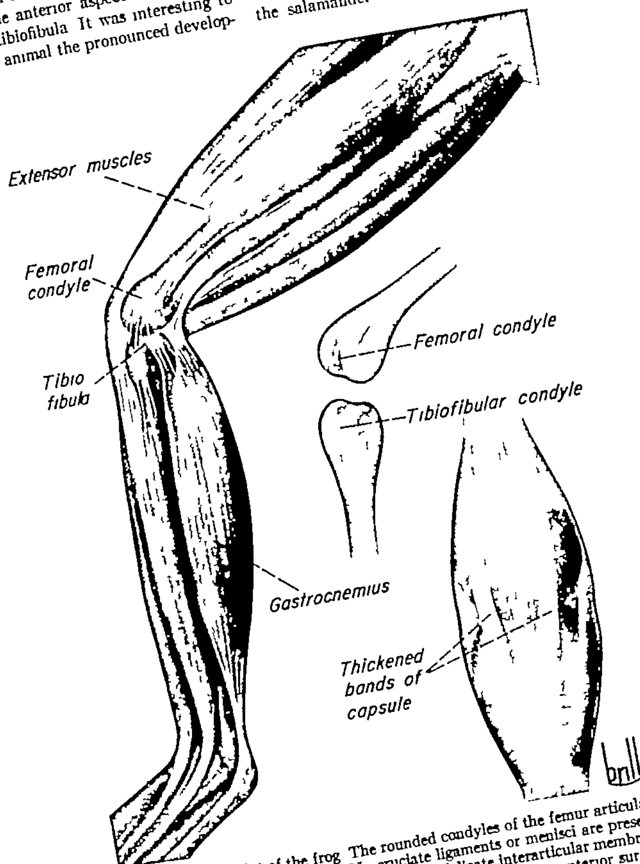


FIG 9 Knee joint of the frog The rounded condyles of the femur articulate with the single bone tibiofibula. No cruciate ligaments or menisci are present. The ends of the bones are enclosed by a thin, delicate interarticular membrane which exhibits several longitudinal thickenings situated on its anterior surface and converged toward the anterior surface of the tibiofibula. This mechanism is capable of powerful and rapid movements

ments or patella are present In spite of the simplicity of the knee joint the hind extremities of the frog are long, powerful and capable of rapid movements

REPTILES

The turtle provides a knee joint which is representative of those of the reptiles. In this classification the extremities reveal advanced development and specialization. The lower leg has two bones—the tibia and the fibula the proximal end of the latter projects beyond the transverse plane of the knee joint and articulates with the lateral condyle of the femur Unlike the configuration noted in the frog the end of the femur terminates in two well formed condyles. Two sharply defined menisci are present. The lateral meniscus continues posteriorly to the inner aspect of the posterior region of the medial condyle of the femur It also has a lateral projection circular in shape, which is interposed between the lateral condyle and the articulating surface of the fibula. The femorofibula joint is at right angles to and continuous with the femorotibia joint. A patella is not present (Fig 10)

MAMMALS

Opossum

The opossum a marsupial provides us with the simplest form of knee joint found in mammals Its extremities show a high scale of development and are adapted to rapid movements The bony components of the knee joint present characteristic and interesting configurations The femur ends in two well formed condyles the medial being slightly larger than the lateral they are oval in shape and are separated by a well-demarcated groove which extends proximally a short distance on the anterior surface of the femur Of interest is the angulation of the tibial plateau which slopes downward backward and laterally The proximal end of the fibula is unusually large and abuts against the lateral condyle of the femur above the level of the joint line Two well formed menisci are present the external meniscus has an extension posteriorly which inserts into the medial condyle and may function as a posterior cruciate ligament A well-defined fibrous structure arises from the articular surface of the medial portion of the tibial plateau which is surrounded by the internal meniscus It extends upward and laterally to insert into the inner aspect of the lateral condyle This structure functions as an anterior cruciate ligament No fibrocartilaginous structure is present between the head of the fibula and the lateral condyle of the femur (Fig 11) Separating the two menisci is a prominent ligamentum mucosum which inserts into the tibia. The extensor apparatus of the knee possesses no patella and ends in two tendons one of which inserts into the upper border of the slanting surface of the tibia and the other into its lower border Immediately in front of the joint a thickening is discernible in the extensor tendon this may be the first alteration in the structure leading to the development of a patella in higher forms

Dog

In the dog the knee joint reveals an architecture designed for rapid and strenuous movements The knee joint is held habitually in a flexed position and is motorized by powerful muscles Around the entire musculature of the extremity is found a dense fascia which together with the extensor muscles restricts to a marked degree the excursion of the patella The patella is an elongated flat bone held at some distance from the joint level A large well formed suprapatellar pouch is present The femur ends in two round condyles of equal size between them is a deep groove with sharply demarcated margins which extends well up on the shaft of the femur This is a feature not prominent in the higher primates and

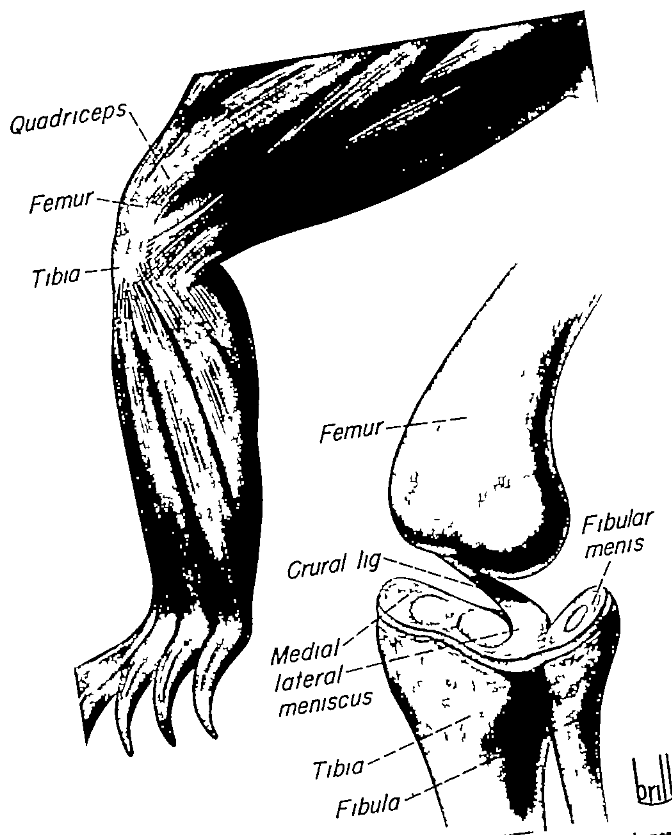


FIG 10 Knee joints of the turtle Note that the lower leg consists of 2 bones, the proximal end of the fibula projects beyond the transverse plane of the knee and articulates with the lateral condyle of the femur Two menisci are present, that the external meniscus continues posteriorly to the inner aspect of the m condyle of the femur and also has a lateral projection, circular in shape, which sep the articular surface of the fibula from the lateral condyle. No patella is present.

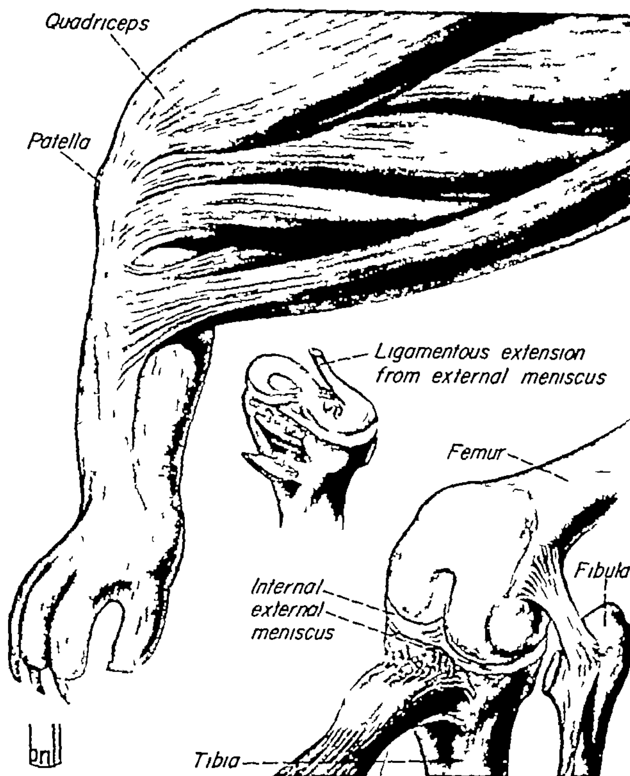


FIG. 11 Knee joint of the opossum The tibial plateau slopes slightly downward backward and laterally the fibula articulates with the tibia Two menisci and fibrous structure comparable with the *anterior cruciate ligament are present Note the thickening* in the terminal end of the quadriceps tendon which may be the first change in this structure leading to the development of a patella in higher forms

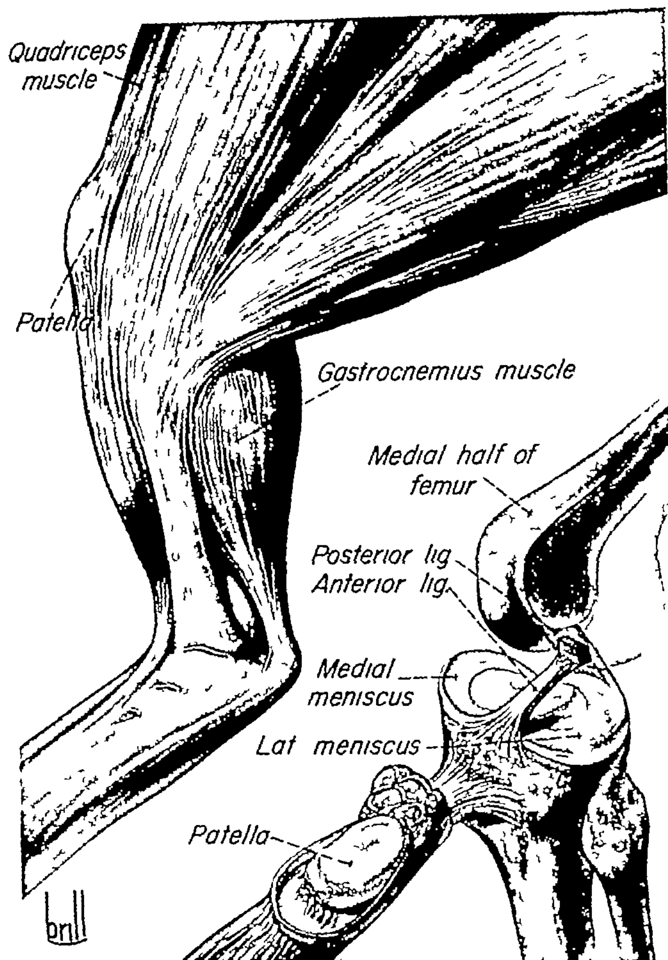


FIG 12 Knee joint of the dog. The patella has very little range of motion and lies at a distance from the joint level It possesses a well-defined patellar groove on the anterior aspect of the femur between the femoral condyles. Note the large infrapatellar fat pad Both cruciate ligaments are present but they are not massive structures The fibula is fused to the tibia below the level of the joint line.

man It seems to be peculiar to animals which are capable of speedy locomotion The patellar tendon is broad and well formed and inserts into a massive prominence on the anterior aspect of the tibia some distance below the joint line A large infrapatellar fat pad is present the ligamentum mucosum inserts into the tibia below and into the intercondylar notch of the femur above

Two well formed menisci are demonstrable the *internal meniscus is almost a complete* circle while the external one is crescent in shape The posterior segment of the external meniscus gives off a fibrous band which continues medially to insert into the outer aspect of the medial condyle of the femur Although the menisci are distinct structures they do not appear to play a major role in the function and the efficiency of the knee joint this is more apparent particularly when the structures are compared with the menisci found in higher primates and man A similar observation was made concerning the cruciate ligaments found in the dog and other lower animals

Both the anterior and the posterior cruciate ligaments are distinct structures but not very massive or sturdy The anterior ligament arises from an area situated between the two articular plateaus of the tibia the posterior cruciate arises from the posterior border of the tibia

The upper end of the fibula is fused to the lateral tuberosity of the tibia below the level of the joint line (Fig 12)

Primates

Macaque Monkey

In this classification the most significant observation was the further development of the cruciate ligaments as compared with *those noted in lower animals This animal's* foot is equipped with a very mobile and opposable hallux hence the foot is used as a prehensile organ Close scrutiny of the movements of this animal reveals that the knees are held habitually in varying degrees of flexion The grasping characteristic of the foot allows the animal to grasp a branch and swing from it to another with pronounced ease Soon it becomes apparent that the execution of such movements imposes considerable traction and rotation stresses on the knee joints in both flexion and extension movements and that the knee joints must be endowed with strong interarticular ligaments to allow such compli*cated strenuous movements*

The lower extremity is very muscular The patella is firmly bound to the anterior surface of the femur by an enveloping fascia and the extensor muscles It is interesting to note that the extensor muscles retain their fleshy state almost to the very point of insertion into the patella The patellar tendon is bound tightly across the joint and inserts into the tibial tuberosity at a distance below the joint line These anatomic features permit the patella a very small range of excursion. The patella is rather broad and quadrilateral in configuration. There is a large well formed suprapatellar pouch The femoral condyles are of equal size and show a pronounced posterior projection They are separated by a clearly demarcated groove which is not so deep or long and with margins which are not so sharp as noted in the dog (Fig 13 A)

Two well formed but delicate menisci are present *The inner meniscus is crescent in* shape while the lateral is an almost complete disk except for a small defect in its center and covers almost the entire lateral plateau of the tibia The inner edges of both *menisci are exceedingly thin* almost transparent From the posterior portion of the external meniscus a fibrous band projects posteriorly to insert into the medial condyle

The cruciate ligaments are broad fibrous *structures capable of providing good stability to the joint It is interesting to note* that the anterior cruciate ligament arises from the articular surface of the inner tibial plateau as a fan-shaped fibrous membrane

which is overlapped by the thin edge of the internal meniscus This anatomic feature is present in the knee joint of the cat but not in that of the dog The fibers on the tibial articular surface converge to form the anterior cruciate ligament, which is sturdier than the posterior cruciate ligament. Such a mode of origin is not present for the pos

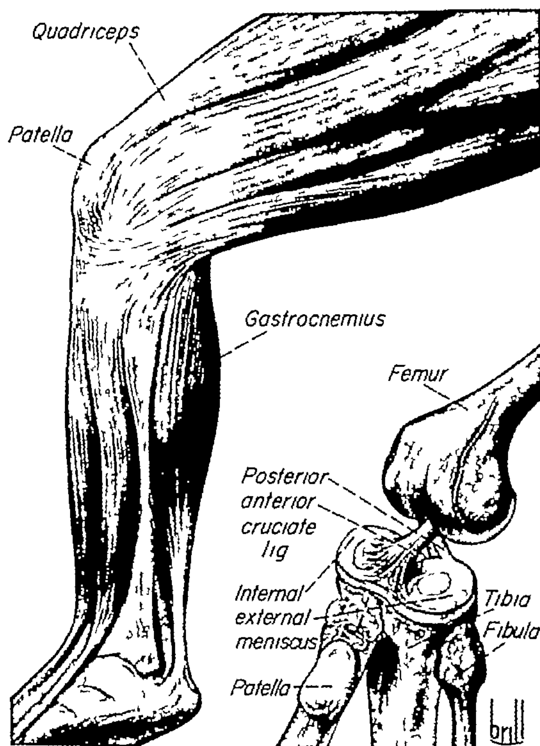


FIG 13 (A) Knee joint of the macaque monkey Note the quadrilateral configuration of the patella the femoral condyles are equal in size and exhibit a prominent posterior projection The lateral meniscus covers the entire lateral tibial plateau except for a small area in its center Note the sturdiness of both cruciate ligaments, the anterior arises from the central portion of the articular surface of the inner tibial plateau

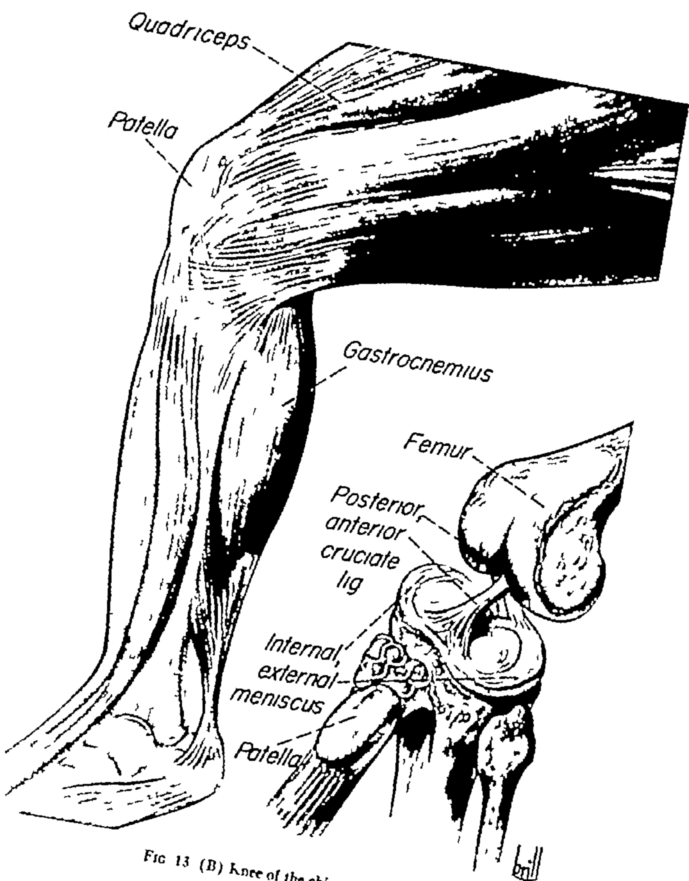


FIG 13 (B) Knee of the chimpanzee

terior ligament, however this structure does gain attachment to the posterior segment of the external cartilage

CHIMPANZEE

In general, the anatomic features of the musculature of the hind limb resemble closely those of the macacque (Fig 13 B) The extremity is motorized by powerful muscles which in the thigh extend almost to the joint line The patella is a relatively small bone and is bound down firmly on

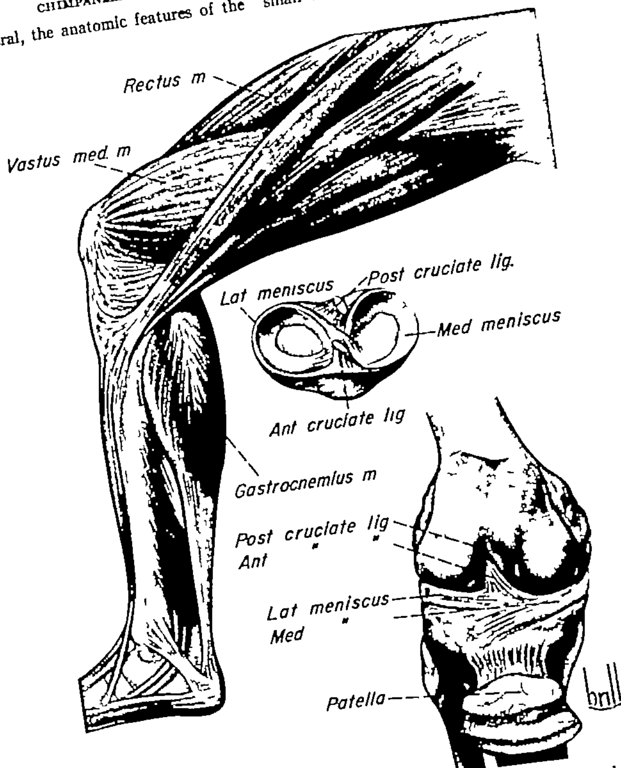


FIG 14 Knee joint of man. The menisci are better developed than in other primates on the other hand the cruciates are less developed. The lateral femoral condyle is larger than the medial and the articular surface of the patella exhibits facets which articulate with corresponding areas on the femoral condyles during flexion and extension of the joint.

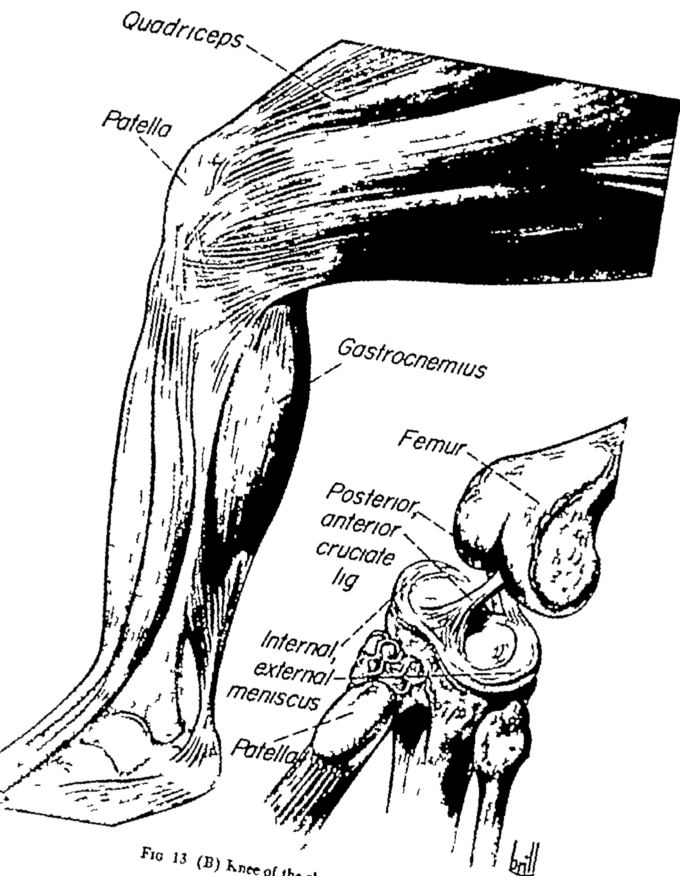


FIG 13 (B) Knee of the chimpanzee

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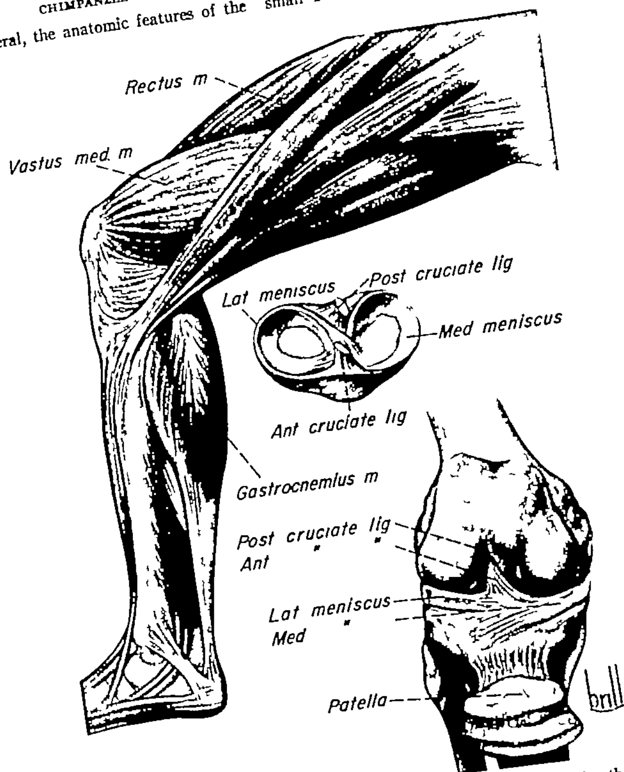


Fig 14 Knee joint of man The menisci are better developed than in other primates on the other hand the cruciates are less developed The lateral femoral condyle is larger than the medial and the articular surface of the patella exhibits facets which articulate with corresponding areas on the femoral condyles during flexion and extension of the joint.

the anterior surface of the femur by the extensor muscles, the patellar tendon and the fascia of the leg. This arrangement greatly restricts the range of motion of the patella. On the other hand the scheme of the interior of the joint is similar to that encountered in man.

This animal tends to assume a semierect posture with the knee held in a habitually flexed attitude. In observing closely, one will see that the chimpanzee uses the hind limbs as organs of support, locomotion and grasping almost as much as the forelimbs. It becomes apparent that strong intra-articular ligaments must be present to provide the extra stability to the knee joints in order that such intricate and strenuous movements can be performed.

The femur ends in two rounded condyles which project posteriorly and are of equal size. Between the condyles is a shallow groove with rounded margins. This configuration of the lower end of the femur differs from that of the macacque in which the groove is deeper and possesses sharper margins but it bears a close resemblance to that found in man. Both menisci are well formed but delicate in structure. The internal meniscus is crescent in shape and anchored firmly to the coronary ligament; the external meniscus resembles an incomplete circle and from its posterior portion a fibrous band is given off which inserts into the medial condyle. The development of the menisci in this animal is greater than that found in lower forms and is surpassed only by that observed in man.

Whereas the menisci are thin narrow delicate structures the cruciate ligaments are broad sturdy cords of fibrous tissue well adapted to the functional demands made on the knee joint. The anterior cruciate which is the larger of the two arises from a broad base on the anterior and central area of the articular surface of the tibia between the two menisci. It bears no resemblance to the origin of the anterior cruciate in the cat or the macacque but approaches the anatomy present in man. The posterior cruciate also is a large and strong ligament. It is attached posteriorly to the external meniscus. A large infrapatellar fat pad and a well-developed ligamentum mucosum are present.

MAN

Man exhibits the highest development of the knee joint. In assuming the erect position new functional demands were made on the musculature motorizing the joint and upon some of the intra-articular components of the joint (Fig 14). The extensors of the leg together with the iliofemoral muscles, especially the gluteal group, now play a major role in maintaining the erect position and the knee in a habitual attitude of extension. Of significance is the greater size of the menisci in man when compared with the size of those in lower primates. This emphasizes the importance of these structures in man. Their role is twofold: they act as buffers between the articular surfaces of the femur and the tibia and they increase the concavity of the tibial plateaus thereby adding to the stability of the joint. The internal meniscus is crescent in form and attached firmly to the internal collateral ligament; the external meniscus is more nearly circular and is attached only to the coronary ligament. It has more freedom than the internal meniscus. The posterior segment of the external meniscus is attached to the posterior cruciate ligament and gives rise to a fibrous band which continues to the outer aspect of the medial condyle (ligament of Wrisberg).

From a comparative viewpoint the cruciate ligaments in man are less developed than those of the chimpanzee and the macacque. One can comprehend this fact readily when the movements of the knee joint are analyzed. The principal motion of this articulation is in one plane—the sagittal plane. Rotary motions such as are observed in the macacque and the chimpanzee are not demanded of the human knee

hence, the role of the cruciate ligaments is less than in the lower forms

Again, to meet the requisites of the erect posture some alteration has occurred in the configuration and the relative size of the femoral condyles. There are two well formed condyles which are separated by a groove which is not so deep or long as that found in the macacque but more pronounced than the one observed in the chimpanzee Of greater significance is the difference in size in the condyles, the lateral one is larger indicating that this condyle transmits the greater portion of the weight in the upright position This is a recent acquisition in man, for embryologic studies disclose that during the development of the knee joint the medial condyle is the larger of the two.

The patella is not bound tightly over the anterior aspect of the femur and has a long range of excursion during flexion and extension of the joint. On its articular surface are found three sets of facets which articulate with corresponding areas on the femoral condyles during varying positions of flexion and extension

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3

Normal Anatomy of the Knee Joint

A study of the anatomy and the functional mechanics of the hip and the knee joints reveals that many muscles of the thigh extend across both joints By changing their fixed points these muscles motorize both joints. Moreover the normal states and the dynamic mechanism of the lower limb are dependent upon the integrity of the hip the knee and the ankle joints, particularly the first two articulations It becomes apparent that any discussion dealing with the anatomy and the mechanics of the knee joint must include the anatomy and the mechanics of the hip joint also

THIGH

Fasciae

The muscles of the thigh are enveloped by two distinct fasciae the superficial fascia or tela subcutanea and the deep fascia or fascia lata.

SUPERFICIAL FASCIA (TELA SUBCUTANEA)

This fascia layer varies in thickness in different regions and contains varying amounts of adipose tissue Anteriorly it is continuous with the superficial fascia of the abdomen and the leg and posteriorly with the fascia overlying the back and the gluteal region It comprises a superficial fatty layer and a deep membranous layer Between the two are located the saphenous vein the superficial inguinal lymph nodes and the superficial vessels and nerves. The superficial fatty layer may be separated into several planes by fine membranous layers This is particularly true in the superomedial aspect of the thigh in individuals possessing considerable subcutaneous adipose tissue The membranous layer fuses with the fascia lata slightly distal to the inguinal ligament and along the superomedial region of the thigh. Also it is adherent to the falciform margin of the fossa ovalis and covers the outlet with a spongy tissue perforated by numerous openings for the blood vessels and the lymph channels. This portion of the membranous fascia filling the fossa ovalis is designated the fascia cribrosa. In the superficial fascia overlying the patella a subcutaneous bursa is situated (prepatellar bursa) frequently another is found over the proximal region of the patellar tendon (infrapatellar bursa)

FASCIA LATA

This deep membranous layer is a dense fascia sheet investing the entire musculature of the thigh Its lateral portion is thick and strong because of the reinforcement it receives from the tendons in this region Where it lacks such reinforcement it is thin and delicate The portion covering the anterior aspect of the thigh contains stout transverse fibers which convert it into a dense fibrous membrane Proximally it gains attachment to the anterior superior spine the pubic tubercle and the inguinal ligament and it is continuous with the *external abdominal and lumbodorsal fascia* Distally it passes over the knee and fuses with the fibrous capsule of the joint and receives contributing fibers from the extensor apparatus chiefly from the vastus lateralis and the vastus medialis This arrangement augments in a large measure the stability of the knee and the strength of the

extensor apparatus of the joint The fascia investing the medial and the posterior regions of the thigh is less dense, in fact, it is thin and does not possess the features of an aponeurotic sheet except in the region of the knee It is attached to the sacrotuberous ligament, the tuberosity and the inferior ramus of the ischium and of the pubis and extends distally to become continuous with the fascia of the posterior aspect of the leg In the region of the knee joint fibers from the tendons of the quadriceps, the sartorius, the gracilis and the semitendinous muscles reinforce the fascia

That portion of the fascia covering the anterior region of the thigh exhibits some interesting anatomic features Proximally, it is attached to the anterior superior spine of

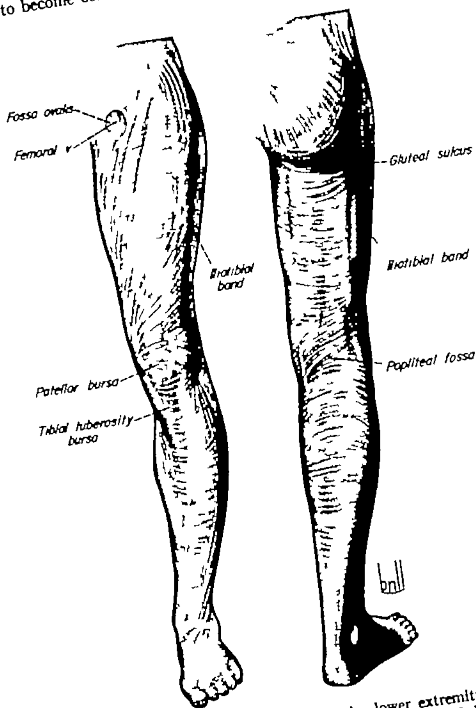


Fig 15 Fasciae enveloping the entire lower extremity Distal to the medial half of the inguinal ligament the outer and deep laminae of the fascia lata sweep around the great saphenous vein to form the fossa ovalis.

the ilium the inguinal ligament and the tubercle of the pubis (Fig 15) Slightly beyond the outer half the inguinal ligament, the three abdominal fasciae blend to form a single aponeurotic sheet. The most superficial of these fasciae is the external fascia passing over the obliquus externus muscle which continues distally superficial to the inguinal ligament. The middle fascia is a prolongation of the transversalis fascia of the antero-abdominal wall it passes distally beneath the inguinal ligament. The internal fascia is an extension of the iliac fascia which also passes beneath the inguinal ligament, the portion below the ligament being designated the iliopectineal fascia. Just beyond the medial half of the inguinal ligament the middle and the internal fasciae do not fuse with the fascia lata and extend distally to form the anterior and the posterior walls of the femoral sheath In the region of the femoral vessels the fascia lata gains in thickness and becomes laminated, it also exhibits an opening (fossa ovalis) through which passes the great saphenous vein The outer lamina together with the inguinal ligament gains attachment to the tubercle of the pubis It possesses a distinct falciform edge which sweeps around the proximal end of the great saphenous vein and continues in the nature of a spiral downward and outward behind the vein to become continuous with the deep lamina along the medial aspect of the vein Between the two laminae some adipose tissue is present

The lateral portion of the fascia lata is noted for its aponeurotic nature and thickness it embodies strong tendinous fibers of insertion of the gluteus maximus and the tensor fascia lata muscles. That portion between the superior border of the gluteus maximus muscle and the crest of the ilium is supplemented by vertical tendinous bundles and is designated the gluteal aponeurosis Along the border of the gluteus maximus this fascia splits into a superficial and a deep layer and invests the muscle The superficial layer is relatively thin (*gluteal fascia*), and from it fibrous septa arise which extend downward between large muscle bundles Proximal and lateral to the greater trochanter of the femur muscular fasciculi terminate in a broad, thick tendon which is continuous with the fascia lata and is known as the iliotibial band Distal to the anterior region of the iliac crest the fascia separates into two layers and envelopes the tensor fascia lata muscle which inserts into the iliotibial band Between the iliotibial band and the vastus lateralis muscle a distinct fascial cleft is present It extends distally, inserting into the tibia and blends with the fibrous expansions from the vastus lateralis and the biceps femoris

At the lower border of the gluteus maximus the layers of fascia enveloping this muscle fuse into one sheet which continues distally over the hamstring muscles and the popliteal fossa. This constitutes the posterior portion of the fascia lata.

From the deep surface of the fascia lata several fibrous septa arise, these pass between the underlying muscles The most significant of these are the lateral and the medial intermuscular septa. Of the aforementioned septa, the lateral intermuscular septum is the stronger it is reinforced by an abundance of longitudinal fibers and its distal portion is by far the thickest. It extends from the insertion of gluteus maximus to the lateral condyle of the femur and separates the vastus lateralis from the biceps femoris Both these muscles fuse with the septum the vastus lateralis joins the ventrolateral surface of the septum and the short head of the biceps femoris the dorsomedial surface The medial intermuscular septum separates the anterior extensor group of muscles from the medial adductor group (between the vastus medialis the adductors and the pectineus muscles) Near the fascia lata the outer portion of the septum separates into two laminae which invest the sartorius It also contributes to the formation of the adductor canal (Hunt

er's canal), which extends from the apex of the femoral triangle to the proximal end of the popliteal space Through Hunter's canal pass the femoral vessels and the saphenous nerve.

Fossa Ovalis. Just distal to the medial end of the inguinal ligament is found an oval aperture in the fascia lata known as the fossa ovalis Through it passes the saphenous vein just before it ends in the femoral vein In this region the fascia lata which is rather thick, separates into two layers between which loose fatty tissue is present. The superficial lamina stretches between and is attached to the inguinal ligament and the tubercle of the pubis presenting a free edge designated as the falciform margin of the fossa Beginning at the pubic tubercle this falciform margin sweeps in the form of a spiral first laterally in which position it lies superficial to the saphenous vein, then downward and medially under the vein Just medial to this vein, both superficial and deep layers merge with each other The upper and lateral segment of the falciform margin is called the superior cornu the distal and medial segment, the inferior cornu The deep layer of the fascia comprises the pectineal the iliopectineal and the iliac fasciae. The aperture (fossa ovalis) is covered by a deep layer of the superficial fascia of the thigh (fascia cribosa) which is perforated by numerous openings for the passage of vessels and lymphatic channels

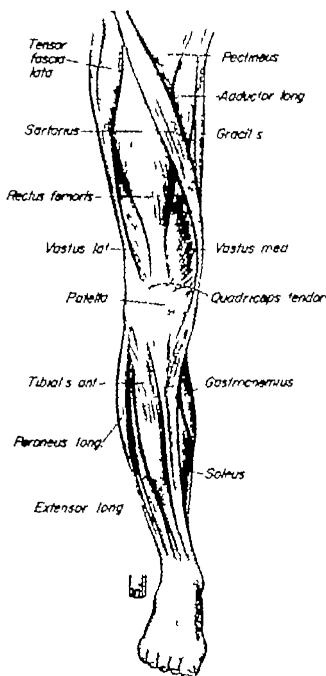


Fig 16 Anterior group of muscles of the thigh and the leg

Muscles

The musculature of the thigh comprises three groups the anterior the medial and the posterior In general each group is concerned with specific actions and possesses a particular nerve supply

ANTERIOR GROUP

This group originally occupied a dorsal position and constitutes the principal flexor of the hip and the extensor of the knee It consists of the sartorius the tensor fascia lata the quadriceps femoris the articularis genu the iliopsoas and the psoas minor (Fig 16)

Sartorius. The most superficial muscle of the anterior group is the sartorius, also called the tailor" muscle It is a long ribbonlike muscle its muscle fibers run parallel with one another and are believed to be the longest in the body The muscle pursues a spiral course extending from the anterior superior spine above to the medial tibial condyle and the adjacent fascia of the

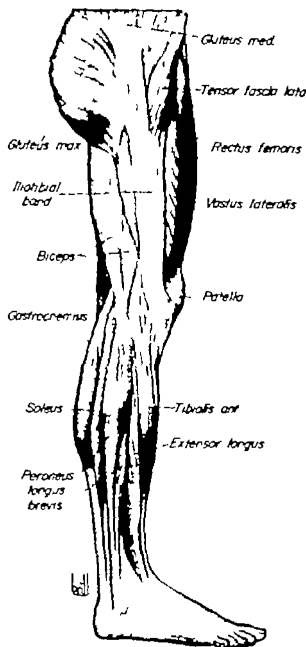


Fig 17 Lateral muscles of the lower leg The origin the course and the insertion of the iliotibial band are clearly shown

leg below The tendon of insertion is first noted at the level of the medial epicondyle of the femur on the undersurface of the muscle Muscle fibers insert into the superficial surface of the tendon as far as the lower border of the knee joint the tendon *then continues forward to its site of insertion* Inasmuch as the muscle spans both the hip and the knee joints it functions as a flexor of the hip and the knee Some authorities believe it to be an initiator of flexion in the hip Flexion of the knee is *possible because it pursues a path posterior* to the axis of motion of the knee joint In addition to the actions described the sartorius is capable of two other functions. Its medial insertion below the knee and its lateral site of origin permit it to rotate the thigh externally Also, it is an abductor of the thigh. Together the four actions of this muscle make possible the cross-legged sitting posture assumed by tailors hence the designation "tailor" muscle.

Tensor Fascia Lata. This muscle is relatively short and flat and arises by a tendinous band *from the external lip of the iliac* crest and the upper half of the notch between the superior and the inferior iliac spines Some fibers of origin arise from the intermuscular septum between the tensor fascia lata and the gluteus medius It follows a course directed slightly posteriorly and inserts into the iliotibial band approximately *at the junction of the upper and the* middle thirds of the thigh The muscle mass is enclosed in two sheets of fascia lata (Fig 17)

Primarily it is a flexor of the hip but its posterior direction allows it to act together with the gluteus medius and minimus as an internal rotator of the thigh Also it *assists these muscles in abduction of the* thigh Furthermore together with the gluteus maximus it sustains extension of the knee through its insertion into the iliotibial band When the foot is set down as in walking and the leg is fixed this muscle advances the opposite side of the pelvis by abducting and flexing the pelvis and *rotating it laterally Finally it assists in* further flexing of the flexed knee joint

Quadriceps Femoris. This is the large fleshy mass covering the anterior medial and lateral surfaces of the femur It comprises four distinct muscles the rectus femoris which occupies the middle of the thigh and also possesses a tendinous origin *from the ilium* the vastus lateralis cover

ing the lateral surface of the femur the vastus medialis, situated on the medial side, and the vastus intermedius, on the front of the femur

RECTUS FEMORIS This muscle mass oc cupies a more anterior position than the other components of the quadriceps femoris muscle It is fusiform in configuration, while the deep fibers continue a straight course to the deep aponeurosis It arises from the ilium by two tendons, one arising from the anterior inferior spine of the ilium and the second from a sulcus just over the brim of the acetabulum The former tendon pursues a straight course and occupies an anterior position, the latter lies more posteriorly and is reflected from its site of origin The ten dons join at an acute angle and fan out into an aponeurotic expansion, which projects downward on the anterior surface of the muscle, and from which the muscle fibers arise. The muscle terminates in a strong aponeurotic sheet which covers the distal two thirds of the undersurface of the muscle and tapers off to form a stout flattened tendon, this inserts into the superior bor der of the patella and ultimately through the patellar ligament into the tuberosity of the tibia Because the muscle crosses the hip joint, it acts as a flexor of the thigh, a function which none of the other members of the group are able to execute Together with the vasti, the rectus femoris extends the knee joint

VASTUS LATERALIS This is the largest member of the quadriceps femoris group, covering the greater part of the lateral and the posterolateral aspects of the femur It arises from several sites Of these, the most important is a broad aponeurosis attached to the upper part of the intertrochanteric line, to the antero-inferior region of the greater tuberosity and in front of the gluteal tuberosity and to the proximal half of the lateral lip of the linea aspera This aponeu rotic expansion spreads out over the super ficial surface of the proximal two thirds of the muscle and from its undersurface many muscle fibers take origin Some fibers take origin from the lateral intermuscular septum situated between the biceps femoris and the vastus lateralis, and some from the tendon of the gluteus maximus The fibers continue distally in a parallel course directed ventro-medially and insert in a thick aponeurosis covering the deep surface of the muscle Fleshy fibers insert into the aponeurosis a short distance from the patella. Ultimately the aponeurosis ends in a strong flat tendon which inserts into the lateral aspect of the patella, fusing with the tendon of the quad riceps femoris Medially, the tendon blends with that of the vastus medialis and dorsally with fibers coming from the tendon of the vastus intermedius also it blends with the capsule of the knee joint. The muscle mass of the vastus lateralis may be separated into two layers, a superficial and deep occa sionally, the latter may be divided further into two muscle sheets

VASTUS MEDIALIS To the casual observer the vastus medialis and the intermedius muscles appear to be united through their entire extent However, if the rectus femoris is removed from the muscular mass one ob serves a narrow plane of division between the two muscles it extends from the medial border of the patella to the distal portion of the intertrochanteric line, where the muscles are often inseparable. The vastus medialis arises from the entire length of the medial lip of the linea aspera and from the distal half of the intertrochanteric line Some fibers also arise from the medial intermus-cular septum and the tendons of insertion of the adductor muscles The fiber bundles run downward and forward and insert into an aponeurosis on the deep surface in the muscle The aponeurosis begins at approxi mately the middle of the muscle near its lateral margin it inserts into the medial proximal half of the medial border of the patella and the tendon of the quadriceps femoris and into the medial condyle of the tibia and the fascia of the leg Also, some fibers join the capsule of the knee joint.

Vastus Intermedius This muscle arises from a large surface area of the femur and covers most of the medial and the lateral surfaces of the femoral shaft Its origin may be described *as arising from the proximal* two thirds of the anterolateral surfaces of the femur and from the distal portion of the intermuscular septum The fiber bundles *insert into the deep surface a superficial* aponeurosis which covers most of the ventral surface of the muscle and inserts into the upper border of the patella forming the deep portion of the quadriceps femoris tendon The proximal fiber bundles continue distally to their insertion in a vertical direction, the medial and the lateral ones take an oblique course Laterally, the tendon of insertion blends with that of the vastus lateralis and medially with that of the vastus medialis

Articularis Genu Beneath the vastus intermedius but distinct from it (occasionally blending with it) is situated a small *group of muscle fibers arranged concentrically*, which arises from the anterior surface of the lower portion of the shaft of the femur This muscle group called articularis *genu inserts into the proximal portion of* the synovial membrane of the knee joint Its function is to draw the synovial membrane upward as the leg is extended

Tendon of the Quadriceps Femoris The combined quadriceps tendon comprises three laminae the superficial layer is formed chiefly by the tendon of the rectus femoris the deep layer by the tendon of the vastus intermedius and the middle layer by the tendons of the vastus lateralis and the vastus medialis (Fig 18) At the lower end of the thigh the aforementioned layers fuse to form a stout single tendon which inserts into the superior and the lateral borders of the patella Some fibers pass over the front of the patella and blend with the fibers of the patellar ligament Some tendon fibers of the vastus medialis and the vastus lateralis fan out and extend distally on each side of the patella to insert into the condyles of the tibia *on either side of the tuberosity* These fibers form the medial and the lateral patellar retinacula, which occupy a position between the anterior and the collateral liga*ments (Fig 19)* Bundles of fibers stretching from the epicondyles of the femur to the patella reinforce the retinacula also into these fibers some fleshy muscle fibers insert

Ligamentum Patellae The central portion of the combined quadriceps tendon continues over the patella to the tuberosity of the tibia as the patellar ligament (anterior ligament) It is a stout, flat tendinous band firmly attached above to the apex and the margins of the patella and below to the tibial tuberosity Its superficial fibers cross over the front of the patella and unite with those of the quadriceps tendon Between the tibia and the tendon a bursa is interposed on the posterior surface of the tendon a pad of fat (infrapatellar fat pad) is found which is lined with synovial membrane and projects into the joint cavity

From the above anatomic characteristics of the components of the quadriceps femoris it becomes apparent that this muscle functions solely as an extensor of the leg Of the *four members of this group the vastus* medialis is by far the most important because as will be shown in the discussion dealing with the mechanics of the knee joint *it is the chief stabilizer of the knee and* is responsible for the last 10° or 15 of extension

Contrary to the belief of many the patella is not a sesamoid bone but develops as part of the femoropatellar joint Its presence ensures the efficiency of the quadriceps muscle by providing additional leverage It accomplishes this by placing the tendon anterior to the axis of motion Moreover the patella affords adequate protection to the articular surfaces of the femoral condyles and spares the quadriceps tendon undue frictional strains All these features must be considered before one is justified in excising the patella

Iliopsoas. Generally this muscle ma s is

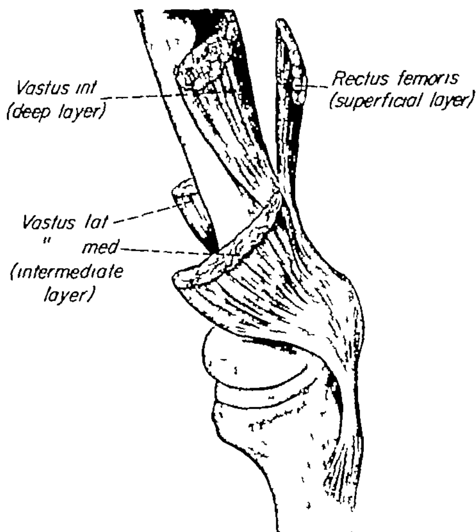


FIG 18 The quadriceps tendon comprises 3 laminae the superficial, the intermediate and the deep

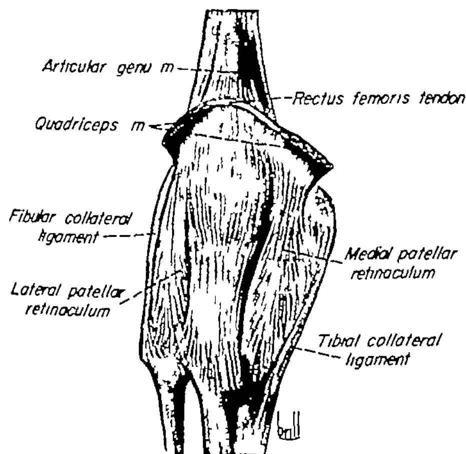


FIG 19 Observe the patellar retinacula occupying the intervals between the anterior and the respective collateral ligaments

considered as consisting of two muscles the iliacus and the psoas Both arise within the abdomen and insert into the lesser trochanter of the femur by a common tendon

The psoas major muscle arises from the sides of the bodies and the corresponding intervertebral disks of 12 thoracic and all the lumbar vertebrae by stout fasciculi (5 in number) each of which is attached to the adjacent superior and inferior borders of 2 vertebrae and to the intervertebral disks from the anterior surfaces, the bases and *the inferior margins of the transverse processes* of all the lumbar vertebrae and from the tendinous arches stretching across the narrowed central portions of the bodies of the lumbar vertebrae Within the posterior substance of the muscle close to its origin and anterior to the transverse processes of the lumbar vertebrae the roots and the branches of the lumbar plexus are situated From their origin the muscle fibers group to form a fusiform muscle which proceeds in a downward direction almost vertically across the brim of the minor pelvis It diminishes gradually in bulk as it approaches its insertion passing under the inguinal ligament and along the anterior aspect of the capsule of the hip joint and terminating in a tendon which joins most of the fibers of the iliacus it inserts into the lesser trochanter of the femur

The iliacus arises within the abdomen as does the psoas major from the ventral margin of the ilium situated between the anterior superior and the anterior inferior iliac spines and the notch between them from the inner lip of the iliac crest and from the base of the sacrum the iliolumbar and the anterior sacro-iliac ligaments From these sources of origin the muscle fibers converge to form a flat triangular muscle and insert in a penniform manner into the lateral border of the tendons of the psoas major some fibers continue distally and insert directly into *the shaft of the femur* just below and in front of the lesser trochanter

The iliopsoas is the most powerful of all the flexors of the thigh at the hip When acting on the free limb (foot off the ground) it functions as an external rotator of the thigh with the leg fixed (foot on the ground), it functions as an internal rotator and in walking it aids in advancing the opposite side of the pelvis. This last action is executed chiefly by the psoas portion of the muscle mass By reversing their fixed points, the iliopsoas muscle flexes the pelvis on the thigh, as in sitting up from a supine position.

Psoas Minor From the sides of the 12 dorsal and the first lumbar vertebrae and from the intervening interarticular disks arises a long narrow tapering muscle called the psoas minor It lies in front of the psoas major it terminates in a flat tendon that inserts into the iliopectineal eminence and the pectineal line its lateral border blends with the iliac fascia. Not infrequently this muscle is absent.

MEDIAL GROUP (ADDUCTOR MUSCLES)

The adductor group is concerned chiefly with adduction and flexion of the thigh originally it occupied a ventral position It comprises the gracilis the pectineus the adductor longus the adductor brevis and the adductor magnus

Gracilis. This muscle is the most superficial of the group it arises by a thin aponeurosis from the inferior pubic and ischial rami and extends downward along the medial aspect of the thigh as a flat ribbon like muscle tapering below and ending in a rounded tendon that curves forward from behind the medial condyle of the femur Close to its insertion the tendon becomes flattened and inserts into the upper portion of the medial aspect of the body of the tibia just below the condyle Some fibers of the tendon continue distally to blend with the fascia of the leg At its insertion the tendon *lies partly under* that of the sartorius and is just above that of the semitendinosus Between the tendons of the gracilis the

semitendinosus and the tibial collateral ligament is situated a small bursa. The gracilis is a flexor and adductor of the thigh, in addition it functions as a medial rotator of the leg when the knee is flexed

Pectineus. This muscle is the most lateral of the group, it is flat and quadrangular and occupies a position in the proximal and medial region of the thigh. It arises from the pectineal line, from the bone in front of it and from the pectineal fascia covering the ventral surface of the muscle From their insertion the muscle fibers run downward, backward and laterally and insert into the raised, roughened bony margin extending from the lesser trochanter to the linea aspera It functions as a flexor and adductor of the thigh

Adductor Longus. This triangularly shaped muscle is situated more superficially than the other two adductors By means of a stout, flat tendon, it arises from the pubic tubercle the tendon soon gives origin to a substantial fleshy muscle which runs downward, backward and inward, paralleling the course of the pectineus muscle It inserts into the medial lip of the linea aspera between the insertions of the vastus medialis and the adductor magnus, the aponeurosis of insertion of the adductor longus blends with both these muscles and with the medial intermuscular septum

Primarily, this muscle is a flexor and adductor of the hip joint but it also functions as an external rotator of the thigh In addition, together with the other adductors from a position of acute flexion it may reverse its action and function as an initiator of extension of the hip

Adductor Brevis. Like the adductor longus muscle it assumes a triangular form It lies under the adductor longus and the pectineus It arises by means of a short narrow tendon from the outer surface of the inferior ramus of the pubis between the gracilis and the obturator externus. From their origin the muscle fibers take a course directed downward, laterally and inward and terminate in an aponeurosis, which inserts into the distal portion of the line extending from the lesser trochanter to the linea aspera and into the proximal portion of the linea aspera just posterior to the insertion of the pectineus and the upper portion of that of the adductor longus Its chief functions are adduction, flexion and external rotation of the hip joint

Adductor Magnus This is the largest and the strongest of the adductor group, it is triangular in shape and occupies a medial position on the thigh. It takes origin from a small area on the inferior ramus of the pubis from the inferior ramus of the ischium and from the tuberosity of the ischium From this origin three distinct groups of muscle fibers are demonstrable (1) The upper fibers run almost a horizontal course from their origin on the inferior ramus of the pubis to their insertion into the superior part of the linea aspera, medial to the gluteus maximus (2) The lower fibers extend almost vertically downward from the tuberosity of the ischium at the distal third of the thigh they end in a strong rounded tendon which inserts into the adductor tubercle of the femur and by means of a broad aponeurosis is attached to the line extending from the tubercle to the linea aspera (3) Between the upper and the lower fibers are found a group which arises from the ramus of the ischium and pursues a course directed obliquely downward and laterally and inserts by means of a broad fibrous expansion into the distal three fourths of the linea aspera Along the line of insertion several openings exist for the passage of the perforating branches of the profunda femoris artery, the most distal opening is the largest and is traversed by the femoral artery and the femoral vein

The adductor magnus has a dual nerve supply the posterior branch of the obturator nerve supplies the upper and oblique muscle fibers and the sciatic nerve supplies the lower and vertical fibers Those fibers ennervated by the obturator nerve are

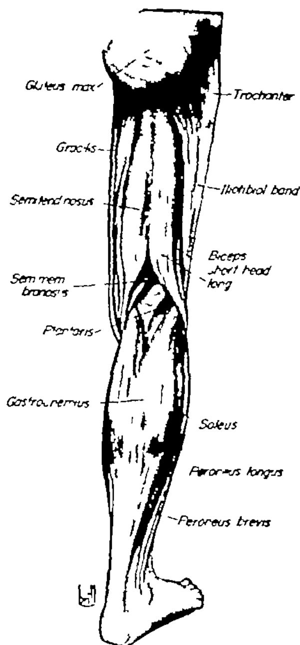


Fig 20 Posterior superficial muscles of the thigh and the leg

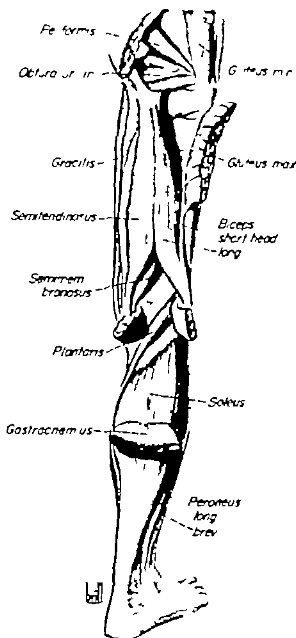


Fig 21 Posterior muscles of the thigh and the leg with the gluteus maximus muscle reflexed showing the origin and the insertion of the two heads of the biceps femoris and the origin and insertions of the other hamstring muscles (semimembranosus and semitendinosus)

chiefly concerned with adduction flexion and external rotation of the hip those supplied by the sciatic nerve function with the hamstring muscles and act as extensors and internal rotators of the hip

POSTERIOR GROUP (HAMSTRING MUSCLES)

This group is primarily concerned with flexion of the leg and rotation of the leg when the knee is flexed also it extends and adducts the thigh (Fig 20) Originally the muscles comprising this group were situated ventrally Mammals below man possess an arrangement of the insertions of the gracilis the semitendinosus and the biceps femoris which favors the fixed flexed position of the knee joint the above muscles

extend more distally than in man and insert chiefly in the fascia of the posterior aspect of the leg The semimembranosus of the lower primates functions primarily as an internal rotator of the leg

As previously noted, the straight portion of the adductor magnus, extending from the tuberosity of the ischium to the adductor tubercle and innervated by the sciatic nerve performs with the hamstring muscles and from a functional viewpoint may be considered as belonging to this group Some observers are of the opinion that the hamstring portion of the adductor magnus is the remains of a muscle which originally extended across the knee joint, and that the tibial collateral ligament represents the remains of the segment of the muscle crossing the joint line to gain insertion into the tibia

Biceps Femoris. This muscle occupies a position on the posterior and lateral aspect of the thigh As its name indicates, it has two heads of origin. The long head arises by a common tendon to it and the semitendinosus from the inner of two impressions on the posterior surface of the tuberosity of the ischium and from the sacrotuberous ligament. The short head arises by short tendinous fibers from the lateral lip of the linea aspera of the femur between the adductor magnus and the vastus lateralis, from the middle of the femur to the bifurcation of the linea aspera from the lateral intermuscular septum and from the upper two thirds of the supracondylar ridge A short distance from the site of origin of the common tendon of the long head fiber bundles appear forming a thick fusiform muscle which runs downward and laterally ending in an aponeurosis on the deep surface of the muscle This aponeurosis of insertion begins approximately at the middle of the back and lateral aspect of the muscle and receives the fibers of insertion of the short head As it continues distally the aponeurosis becomes condensed into a stout tendon which winds around the superficial layer of the lateral collateral ligament and inserts into the outer aspect of the head of the fibula. It sends a small fibrous projection to the lateral condyle of the tibia and into the fascia of the leg (Fig 21)

The chief function of the biceps femoris is to extend and adduct the thigh and to flex the leg, the short head acts only on the leg In addition, the long head assists in external rotation of the thigh, also, it is an external rotator of the leg when the knee is flexed Study of the origins and the insertions of the hamstring muscles discloses that they resemble the anterior group of muscles in that they cross two joints which flex in opposite directions

Semitendinosus. This muscle arises from a tendon common to it and the long head of the biceps femoris from the mediodorsal impression on the tuberosity of the ischium and from an aponeurotic sheet joining the adjacent surfaces of the proximal portions of the semitendinosus and the long head of the biceps The fiber bundles form a flat fusiform muscle belly that terminates at the middle of the shaft of the femur in a long tendon of insertion that passes behind the medial condyle of the femur, then curves forward and ends in a triangular fibrous expansion that inserts into the proximal portion of the medial surface of the body of the tibia, extending almost as far as the anterior crest of the tibia As it runs forward the tendon crosses the tibial collateral ligament of the knee joint a bursa is interposed between the two structures At its insertion the tendon lies below that of the gracilis and is overlapped by that of the sartorius it sends out a fibrous expansion which blends with the deep fascia of the leg A bursa (anserine bursa) intervenes between the tendon of insertion of the sartorius on the one hand and the tendons of the semitendinosus and the gracilis on the other this bursa may exist as an extension of the bursa between the semitendinosus and the tibial collateral ligaments or it may exist as a separate bursa The arrangement of the tendons of insertion of the sartorius, the

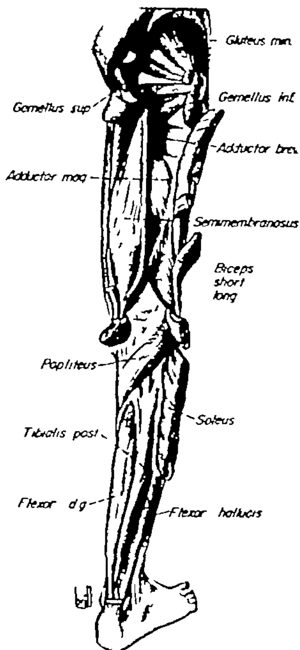


FIG 22 Deep muscles of the posterior aspect of the thigh. Note the anatomic arrangement of the adductor magnus the semimembranosus, the intermuscular septum and the short head of the biceps femoris.

semitendinous and the gracilis is often re ferred to as the pes anserine At about the middle of the semitendinosus a tendinous septum divides the belly into a proximal and a distal segment

It functions as an extensor an adductor and an internal rotator of the thigh and a flexor of the leg when the knee is flexed it acts as an internal rotator of the leg

Semimembranosus (Fig 22) This muscle occupies a position on the posterior and medial aspect of the thigh It arises by means of a broad flat tendon from the su perior, lateral facet in the tuberosity of the ischium between the tendons of the biceps femoris and the quadratus femoris Soon after its origin the tendon gives rise to a broad aponeurotic sheet which covers the proximal portion of the anterior surface of the muscle From this fibrous expansion fiber bundles arise which converge to form a second fibrous layer covering the distal half of the posterior surface of the muscle. Then it contracts to form a stout tendon of insertion which inserts into the posterior aspect of the medial condyle of the tibia and sends out a fibrous prolongation that is projected obliquely upward and laterally blending with the capsule of the knee joint to form the oblique popliteal ligament This ligament inserts into the lateral condyle of the femur the tibial collateral ligament, the deep fascia of the leg and the fascia cover ing the popliteus muscle Between the joint capsule and the tendon of the semimembra nosus a bursa is interposed which in some instances communicates with the cavity of the knee joint and as a rule continues down ward to occupy a position between the semi membranosus and the medial head of the gastrocnemius

The semimembranosus functions as an extensor an adductor and an internal rotator of the leg it flexes the leg and rotates it internally

KNEE JOINT

The knee joint is the most massive joint of the human skeletal system also it is the most superficial and the most vulnerable Nature has endowed this articulation with distinctive anatomic features which adapt it to meet the varied static and dynamic functional demands made upon it by man

Femur
Vastus intermedius
lateralis
Rectus femoris
Iliotibial band
Vastus internus
Sartorius
Superf vessels
Sciatic n
Adductor long
Saphenous v
Biceps
Gracilis
Adductor magnus
Semimembranosus
Deep femoral vessels
Semitendinosus

FIG 23 Cross section through the middle of the thigh.

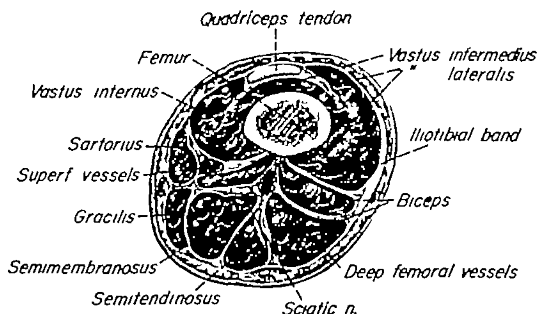


FIG. 24 Cross section through the distal third of the thigh.

To meet the constantly changing stresses on the joint during weight bearing and to fulfill adequately the mechanism of propulsion of the body in locomotion the articulating bones comprising the knee joint are unusually massive, and yet their configuration is such that free and easy motion is executed The joint is situated at the ends of the longest bones in the body predisposing it to great stresses in all planes these stresses are neutralized by a network of stout ligamentous supports Finally the requirements of the acts of balance and propulsion have been responsible for the evolvement of a

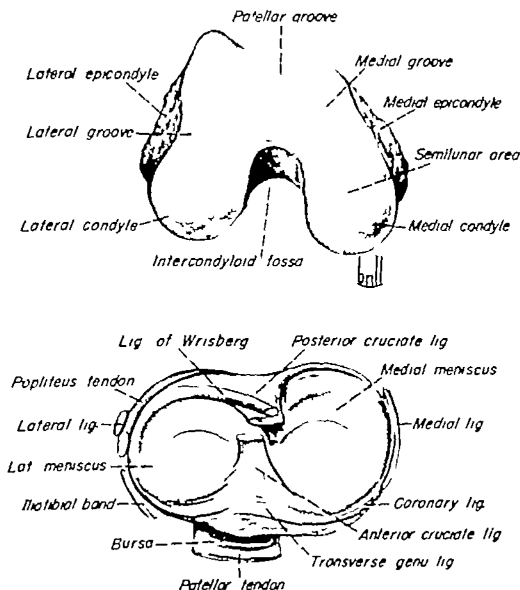


FIG 25 Note the massive configuration of the femoral condyles and the location of the epicondyles There are 3 articular surfaces the femoral condyles and the articular surface on the anterior surface of the femur which articulates with the patella. The bottom figure depicts the corresponding articular surfaces on the tibia and the relation of the intra articular ligaments and the collateral ligaments Also observe the relation of the popliteus tendon to the fibular collateral ligament and the lateral meniscus. The medial and lateral grooves on the articular surfaces of the femoral condyles are clearly shown.

muscular apparatus motorizing this articulation, powerful on one hand and complicated and delicate on the other This intricate muscular development allows both coarse and refined movements at the knee joint in the sagittal plane and in a rotatory direction

From a functional viewpoint, the knee joint is a compound joint consisting of three articulations enclosed by one fibrous joint capsule Two of these are condyloid in type situated between each of the condyles of the femur and the corresponding condyles of the tibia, a meniscus is interposed between each set of condyles. The third articulation approaches the arthroidal type and is situated between the patella and the femur Pronounced incongruity of the articulating surfaces of the patella and the femur exists in the joint after the third year of life, so that the gliding movements of the patella over the femur are not similar to those of a true arthroidal joint. The anterior and the posterior cruciate ligaments situated in the middle of the joint and the ligamentum mucosa and the alar ligaments tend to divide arbitrarily the synovial cavity into smaller lateral and medial cavities The cruciate ligaments may be regarded as collateral ligaments of the medial and the lateral femorotibial joints

Condyles of the Femur

The distal end of the femur terminates in two rounded, expanded articulating surfaces —the femoral condyles—that articulate with the upper end of the tibia (Fig 25) A third articulating surface is located on the anterior surface of the distal end of the femur over it the patella glides backward and forward during flexion and extension of the knee joint. Medially and laterally immediately proximal to the condyles irregular elevated areas are present which comprise the medial and the lateral epicondyles The upper portion of the medial epicondyle gives rise to a sharp elevation designated as the adductor tubercle On its posterior surface the middle one third of the femur is reinforced by a prominent longitudinal bony ridge, the linea aspera, exhibiting a medial and a lateral lip and an irregular intermediate line Below, the linea aspera continues as two diverging roughened crests, the medial and the lateral supracondylar lines They enclose between them the popliteal surface of the femur, a triangular area over which pass the popliteal vessels. The lateral ridge is elevated more than the medial and it continues as far as the superior aspect of the lateral condyle The medial ridge is less prominent and is projected downward as far as the superior aspect of the medial condyle where it terminates in the adductor tubercle

As previously noted, the condyles of the femur are separated in front by the patellar surface, behind, they project posteriorly, forming massive rollers which are separated by a deep interval, the intercondyloid fossa Also, as they continue posteriorly and inferiorly they diverge slightly Of the two condyles, the lateral is the more prominent it is broader both in the anteroposterior and the transverse planes Although the medial condyle is less prominent it projects distally to a lower level than the lateral when the shaft of the femur is held in a true perpendicular plane Normally the femoral shaft is held in a slight oblique plane hence producing a valgus condition at the knee joint in this position the distal articular surfaces of both condyles are in the same transverse plane While the bony axis of the lateral condyle is almost in a true anteroposterior plane that of the medial condyle courses backward and medialward. The sagittal course of both condyles forms circles whose radii become progressively smaller, forming spiral curves the radii of the spiral curve of the lateral condyle are longer than those of the medial

The patellar surface exhibits a medial groove and a medial and a lateral convexity the lateral convexity is more prominent and broader and projects upward to a higher

the femur just below the greater tuberosity and extend along curved pathways across the greater trochanter ending at its superior surface They cross the trabeculae arising on the opposite side, their function is primarily to strengthen stability of the neck of the femur In the aged these trabeculae are frequently absent

Trabeculae comprising the principal tensile group arise from the lateral surface of the femur distal to the calcar femorale. They arch upward and medialward in smooth convex lines which tend to run parallel with one another, crossing the neck of the femur and ending in the inferior region of the femoral head Compared with the bony plates of the compressive groups, these *trabeculae* are thinner and more widely *spaced*, they intersect the trabeculae f the opposite side at right angles Upon group the upper end of the femur dep considerably for its tensile strength

The trabeculae of the secondary te *group arise* from the outer surface of shaft below the principal tensile *trabec* They too arch upward and medially, c ing the axis of the femur and ending beyond the mid line, they intersect trabeculae from the opposite side at r angles

As pointed out by Koch the trabec of the tensile system are thinner and r delicate than those of the compressive tem in corresponding positions the st ness of the lamellae varies with the inten of the stresses acting at any given poin

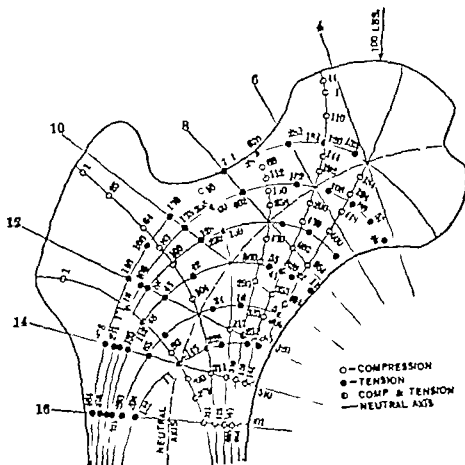


FIG 27 Intensity of maximum tensile and compression stresses in upper femur Computed for load of 100 pounds on right femur (after Koch) (Goss Gray's Anatomy Philadelphia Lea & Febiger)

becomes apparent that the trabeculae of the compressive group are subjected to greater loads than those of the tensile group in corresponding positions. To illustrate this point, in Figure 27 one notes that the maximum tensile strength at Section 10 in the trabeculae occupying a superior position is 150 pounds per square inch, on the other hand, the corresponding point in the compressive system discloses compressive stresses of 404 pounds per square inch It also becomes obvious that the trabeculae are arranged in pathways of maximum tensile and compressive stresses, a pattern which permits the trabeculae to carry the load in the most economical manner Based on this observation, Koch recorded that the above configuration was in accordance with the mechanical principle stating that the most direct manner of transmitting stresses is in the direction in which the stresses act. The intensities of the vertical shear diminish as the lower level of the upper end of the femur is approached paralleling this change the amount of bony material in the spongy portion of the upper end of the femur varies in proportion to the intensity of the shearing stresses at the various sections. In accordance with this mechanical law one notes that the pattern of the bony plates in the upper end of the femur is such that the greatest strength is attained with a minimum of material

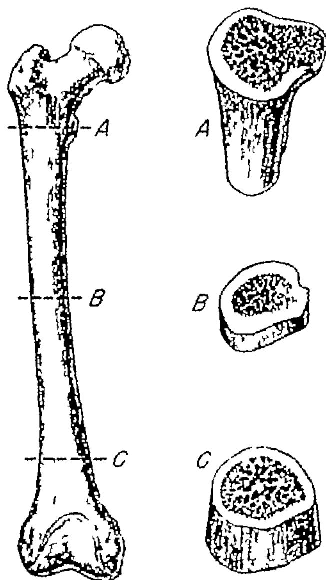


Fig 28 Tubular structure of the shaft of the femur at the identical levels This pattern follows specific mechanical laws so that minimal amount of bony substance is capable of securing great strength.

The shaft of the femur also conforms to and illustrates the aforementioned mechanical principle In the shaft both vertical and horizontal shearing stresses are minimal in intensity hence the minimal amount of material is required to resist these forces which are best counteracted by material being near the neutral plane The shaft reveals very little material in its central region or neutral plane the bony trabeculae resisting the forces of stress are found near the neutral axis in the compact bone This arrangement also resists most effectively those stresses tending to bend the bone which result from the load on the head of the femur and other loads tending to bend the shaft in other planes Of special significance to meet the above stresses is the tubular structure of the shaft of the femur Here again one observes that a minimum amount of bony substance is capable of securing great strength because its arrangement follows specific mechanical laws (Fig 28)

Inner Structure of the Distal End of the Femur

The distal end of the femur reveals a

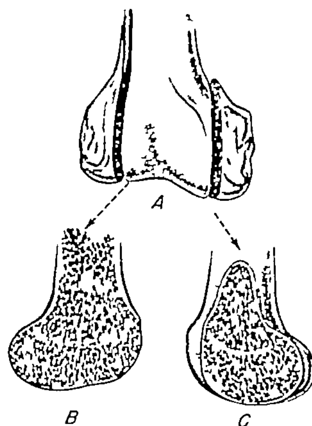


Fig 29 The distal end of the shaft of the femur flares out to form two massive femoral condyles. As the distal end is approached the compact bone becomes progressively thinner and the cancellous bone increases in amount

constructural design suitable to transmit effectively the loads of the femur through the knee joint Stability in a large joint such as the knee requires that the distal end of the femur be relatively massive but its architectural configuration should be such that it be as light as is consistent with the required strength To meet these requisites the resisting trabeculae should be arranged in lines parallel with the direction in which the stresses act and in the paths taken by the stresses The most efficient manner to achieve these objectives would be to project the innermost trabeculae as straight lines parallel with the longitudinal axis of the shaft of the femur gradually to flare the outer layers of compact bone outward and at the same time to continue giving off filaments of bone parallel with the longitudinal axis as the terminal regions of the femur are approached In addition the above filaments should be braced by struts placed transversely and each should carry its proportionate share of the total load, transmitting it to the articular surface of the femur in a plane perpendicular to that surface

Study of the intrinsic configuration of the distal end of the femur reveals that it conforms to the above mechanical plan (Fig 29) The distal end of the shaft of the femur flares out to form the two massive femoral condyles Simultaneously, as the distal end is approached the compact bone becomes progressively thinner and the cancellous bone increases in amount Two systems of trabeculae are discernible—a longitudinal and a transverse system The longitudinal trabeculae spring from the inner wall of the shaft of the femur and are prolonged distally in straight lines parallel with the shaft of the femur as far as the epiphyseal line they then continue in smooth curved lines to the articular surface meeting that surface at right angles at every point Near the center of the bone the above longitudinal filaments give rise to other fine delicate longitudinal trabeculae to which they are connected by fine transverse trabeculae lying in planes parallel with the sagittal plane Unlike the stout sturdy longitudinal trabeculae the transverse trabeculae are delicate and lighter in structure They are placed at right angles to the longitudinal lamellae acting as struts

Patella

The patella is a flat sturdy bone triangular in cross section occupying a position on the front of the knee joint It is composed chiefly of compact cancellous tissue and presents an anterior and a posterior surface two borders an apex and a base (Fig 30) Contrary to the belief of many observers the patella is not a sesamoid bone This observation emphasizes the importance of the role that the patella plays in the normal

mechanics of the knee joint, a role which too many workers tend to minimize

Its anterior surface is slightly convex, traversed by many longitudinal striae and perforated by numerous small openings for the passage of nutrient vessels In the recent state, this surface is covered by an extension from the tendon of the quadriceps femoris (suprapatellar tendon) which fuses below with the superior fibers of the ligamentum patellae (infrapatellar tendon) Between the skin and the anterior surface is a well defined bursa which occasionally may be loculated

The posterior or articular surface is covered in the recent state by a thick layer of hyaline cartilage It is oval in outline and is divided into a lateral and a medial portion by a vertical ridge The medial and the lateral areas or facets correspond to the patellar surfaces on the medial and the lateral condyles of the femur the lateral articular surface is the larger In the adult patella, transverse ridges acquired after birth are discernible and divide the patella into functional areas, opposing the articular surface of the femur in different positions of the knee joint Just distal to the articular surface is a rough convex area which affords attachment to the ligamentum patellae the upper portion of this nonarticular region is separated from the head of the tibia by a pad of adipose tissue

The base or superior border of the patella is broad and slopes downward and forward It provides attachment for the fibers of the quadriceps tendon, derived chiefly from the rectus femoris and the vastus intermedius muscles On either side of the patella are the medial and the lateral borders, which are thinner than the base and converge to the apex They give attachment to the majority of the fibers derived from the vastus medialis and the vastus lateralis The apex of the patella is directed slightly inferiorly and into it inserts the ligamentum patellae.

PROXIMAL EXTREMITY OF THE TIBIA

The upper end of the shaft of the tibia is expanded to form two large eminences,

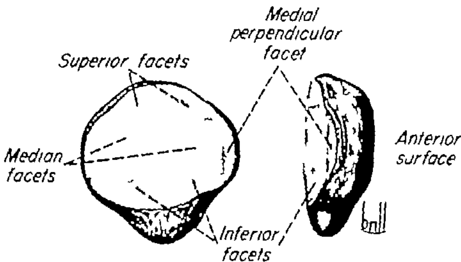


FIG 30 Articular surface of the patella, showing the vertical or perpendicular ridge and the superior, median and inferior facets which articulate with corresponding areas on the lateral and the medial condyles of the femur in different positions of the knee joint.

the lateral and the medial condyles (Fig 31) Its upper surface is smooth and articulates with the condyles of the femur It comprises two facets or plateaus. The medial facet is oval in outline and is slightly concave from side to side and from front backward, it articulates with the medial condyle of the femur The lateral facet is circular in shape, smaller and almost flat however closer inspection reveals it to be slightly concave from side to side and slightly convex from front backward, particularly on its posterior surface It receives the lateral condyle of the femur Only the central portion of each facet articulates with the corresponding condyle of the femur the periphery of each facet is covered by a fibrocartilaginous meniscus which is interposed between the tibia and the femur and attached to the borders of the tibial condyles by *fibers derived from the capsule of the* knee joint. Separating the two articular surfaces is a rough irregular interval which is depressed anteriorly forming the anterior intercondyloid fossa it provides attachment for the medial and the lateral menisci and the anterior cruciate ligament In the center of this interval (slightly more posteriorly than anteriorly) rises the intercondyloid eminence which presents a medial and a lateral *intercondylar tubercle onto* which the articular facets are projected The posterior horns of the medial and the lateral menisci are attached to the posterior region of the base of the intercondyloid eminence Posteriorly the condyles are separated by a deep rough depression the posterior intercondyloid fossa which gives attachment to a portion of the posterior ligament of the knee joint and to the posterior cruciate ligament Anteriorly, the condyles of the tibia are connected by a flat triangular surface whose distal region terminates in an oblong prominence, the tibial tubercle which provides attachment for the ligamentum patellae

A bursa is interposed between the superior surface of the tibial tubercle and the

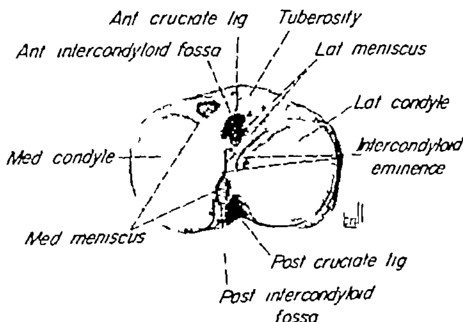


Fig 31 Superior surface of tibia showing the two plateaus the medial and the lateral intercondylar tubercles the anterior and the posterior intercondylar areas and the points of attachments of the anterior and the posterior horns of the menisci

deep surface of the ligamentum patellae A deep transverse sulcus traverses the posterior aspect of the medial condyle, in it the tendon of the semimembranosus muscle finds attachment The medial surface of the medial condyle is directly under the skin It is also prominent and assumes a convex configuration, it provides an attachment for the tibial collateral ligament The lateral tibial condyle also presents a convex lateral surface which is prominent and rough and occupies a subcutaneous position Slightly anterior to the middle of the lateral surface of the lateral condyle and on the same level as the tuberosity of the tibia a rough prominence arises into which inserts the iliotibial band Posteriorly, this condyle exhibits a facet which is flat and almost circular in outline, it faces downward, backward and laterally and articulates with the articulating surface of the fibula The periphery of the facet is rough and provides attachment for the ligaments of the superior tibiofibular joint

The proximal end of the fibula, the head, is a rounded expansion of the upper end of the shaft and is responsible for the palpable eminence on the lateral and posterior aspect of the lateral condyle of the tibia On its medial surface it presents an articular facet circular in shape, directed upward, forward and medially, articulating with the lateral condyle of the tibia A rough prominence is situated on the superior surface of the

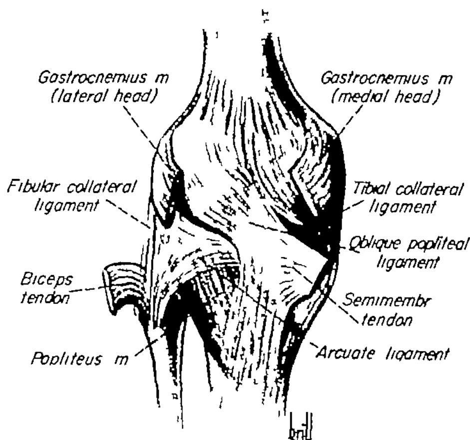


FIG 32 Posterior aspect of the knee joint, showing the origin of the oblique popliteal ligament from the tendon of the semimembranosus. This ligament lies posterior to the posterior cruciate ligament and reinforces the posterior portion of the joint capsule

head which gives attachment to the tendon of the biceps femoris and the fibular collateral ligament of the knee joint the tendon is divided into two sections by the ligament On the lateral aspect a rough eminence projects upward and posteriorly, terminating in a pointed prominence designated as the apex Into it inserts the arcuate ligament of the knee joint

Capsule and Ligaments of the Knee Joint

FIBROUS CAPSULE

The articular cavity of the knee joint is *enclosed by a thin strong fibrous capsule* which is reinforced on all sides by numerous bands of fibrous tissue Its weakest portion *is situated anteriorly beneath the tendon* of the quadriceps femoris In this region the fibrous membrane is very thin and does not *exist as a distinct separate structure but* blends with the undersurface of the quadriceps tendon while the synovial membrane *lining the capsule is very prominent. The* fascia lata and the tendons located in the vicinity of the knee joint provide expansions of reinforcing fibrous tissue Anteriorly the capsule is strengthened by fibrous expansions derived from the vasti the fascia lata and the iliotibial band *these* comprise the medial and the lateral patellar retinacula Posteriorly its proximal attachment is immediately *adjacent to the articu*lar borders of the two femoral condyles and the margins of the intercondyloid fossa of the femur *It fuses with the sides of the* posterior cruciate ligament The posterior portion of the capsule is strengthened by a stout expansion *from the tendon of the* semimembranosus which is directed upward and laterally and designated as the oblique popliteal ligament *this structure lies pos*terior to the cruciate ligaments (Fig 32) Medially it fuses with the tibial collateral ligament and receives *fibers of reinforce*ment from the semimembranosus and the sartorius muscles Laterally it is separated *from the fibular collateral ligament* by the tendon of the popliteus muscle, which pierces the fibrous capsule to gain entrance *into the joint cavity* This region is augmented by bands projected from the iliotibial band they occupy the space between *the fibular collateral ligament* and the oblique popliteal ligament

LIGAMENTUM PATELLAE

It was previously recorded that the ligamentum patellae is the chief anterior liga*ment of the knee joint Essentially* it comprises the central portion of the tendon of the quadriceps femoris muscle which is *projected over the anterior surface of the* patella to its site of insertion on the tuberosity of the tibia (Fig 19) It is a flat tendi*nous structure about 2½ to 3 inches long* firmly anchored above to the apex and the borders of the patella and to the irregular *depression on its posterior surface* The fibers of the tendon of the quadriceps femoris blend with those of the ligamentum *patellae on the anterior surface of the pa*tella Interposed between the synovial membrane of the knee joint and the posterior *surface of this ligament is a large pad of fat* (infrapatellar fat pad) and a bursa is found between the tibia and the ligament

PATELLAR RETINACULA

This structure strengthens the lateral and *the medial portions of the fibrous capsule* it comprises fibrous strands prolonged from the tendons of the vastus medialis and the *vastus lateralis Proximally the fibers are* attached to the anterior aspect of the lateral and the medial margins of the patella they *continue distally along the sides of the liga*mentum patellae and insert into the tibia filling the interval between the collateral *ligaments* and the ligamentum patellae Laterally the above fibers are continuous with the fascia lata and the iliotibial band medially they blend with the periosteum of the shaft of the tibia below the oblique line (Fig 19)

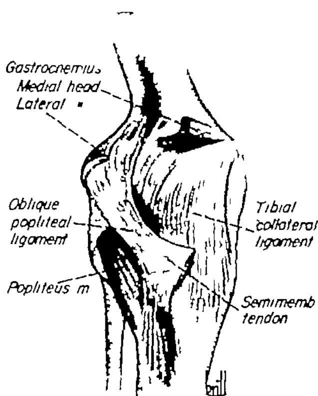


FIG 33 Posteromedial aspect of the knee, showing the triangular shaped tibial collateral ligament. It includes long vertical anterior fibers and short oblique superior and inferior fibers, its widest portion is directly opposite the medial meniscus

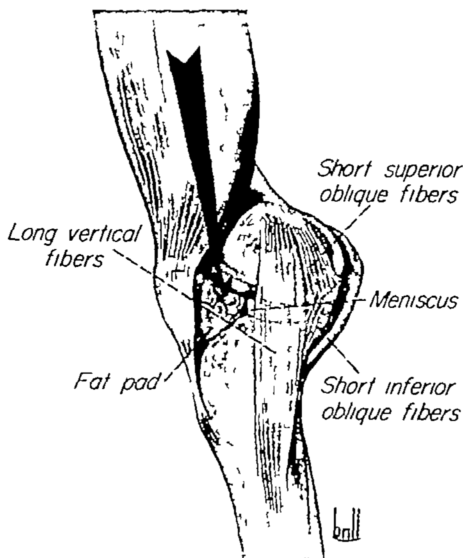


FIG 34 Showing relation of the triangular tibial collateral ligament to the medial meniscus. Also observe the direction of the anterior vertical fibers and the direction of the short superior and the inferior oblique fibers, also note that the anterior portion of the femoral condyle compresses the semilunar fat pad and not the meniscus.

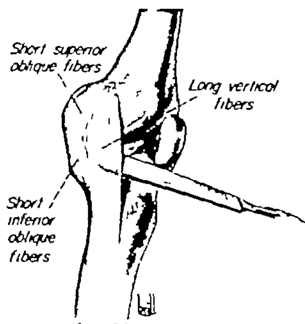


FIG 35 Drawing of an anatomic dis section, showing the interval between the anterior vertical border of the tibial col lateral ligament and the medial meniscus.

TIBIAL COLLATERAL LIGAMENT
(INTERNAL LATERAL LIGAMENT)

This is a flat broad triangular fibrous *structure possessing great strength* it plays an important role in the stability of the knee joint (Fig 33) From a morphologic viewpoint this structure consists of a deep and a superficial layer

The deep layer is the smaller and com prises thickened vertical fibers of the joint capsule Proximally, it is attached to the medial epicondyle of the femur and distally to the articular margin and the medial sur face of the shaft of the tibia It is firmly adherent to the periphery of the medial meniscus and its anterior and posterior bor ders are continuous with the fibrous capsule of the joint

The superficial layer covers completely the deep or capsular layer it is this portion of the ligament which assumes the flat tri angular shape described above It is ap proximately 10 4 cm long and runs slightly forward from above downward *It consists* of long vertical anterior fibers and short oblique superior and inferior posterior fibers the widest portion is directly over the medial meniscus Above it inserts into the femur just distal to the adductor tuber cle and into the medial epicondyle of the femur below the anterior portion inserts into the medial aspect of the shaft of the tibia 4 5 cm distal to the articular margin The fibers of insertion continue downward on the medial aspect of the tibia for ap proximately 3 more centimeters It becomes apparent that the ligament is not attached to the tibia throughout its entire length (Fig 34) In many instances a bursa exists between the upper portion of the tibia and the ligament a bursa was present in 96 per cent of the specimens studied The oblique posterior fibers tend to converge backward toward the joint line and blend with the periphery of the medial meniscus Some fibers continue downward to gain insertion into the upper border of the groove for the tendon of the semimembranosus others cross the tendon to the lower border of the groove and still other fibers are continuous with the anterior vertical portion of the *medial ligament The anterior vertical bor* der is free and not adherent to the menis cus in fact a bursa is found occasionally at this site (Fig 35) All anatomic speci mens studied revealed that proximal to the joint space the deep and the superficial layers of the tibial collateral ligament blend into one fibrous structure The layers can not be separated by sharp dissection Distal to the joint space a projection from the ten don of the semimembranosus separates the two layers below this point the inferior medial genicular vessels and nerves pass be neath the medial ligament separating it from the shaft of the tibia (Fig 36) In contradiction to the belief of many observ ers the tibial collateral ligament is not firmly attached to the capsule and the pe riphery of the medial meniscus Careful di section of this region reveal that the cornu i *of the meniscus are free and* that the periph ery of the anterior segment and the capsule

in this region are only loosely attached to the ligament The two strata can be separated readily by blunt dissection, occasionally a bursa is interposed between the two However, just posterior to its center the meniscus fuses firmly with the fibrous capsule and the posterior oblique fibers of the ligament. This fixed juncture tends to restrict but not eliminate the forward and backward excursion of the meniscus during extension and flexion of the knee joint and also plays a pertinent role in the abnormal mechanics of the joint responsible for injury to the meniscus The distal portion of the tibial collateral ligament is crossed by the tendons of the gracilis and the semitendinosus muscles and by the expansion of the sartorius muscle being separated from these structures by the bursa anserina From the medial border of the patella strong, curved retinacular fibers pass to and fuse with the proximal portion of the anterior border of the ligament.

Some authorities are of the opinion that the strong anterior portion of the medial ligament is morphologically the continuation of the tendon of the hamstring part of the adductor magnus, which inserts into the adductor tubercle and is ennervated by a branch from the sciatic nerve This concept is not confirmed by study of the embryologic development of the knee joint The lateral ligaments develop as distinct structures from the same tissue which forms the fibrous capsule In the regions of the lateral aspects of the knee joint destined to be oc

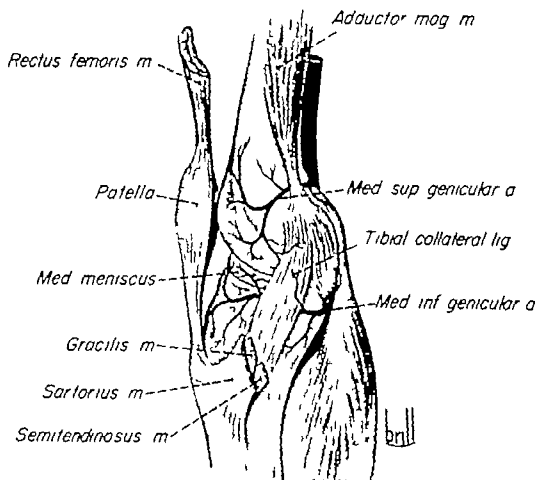


Fig 36 Relation of the superior and the inferior medial genicular vessels and nerves to the tibial collateral ligament note that the inferior structures lie beneath the ligament separating it from the tibia. Observe the arterial anastomosis on the medial side of the joint

cupied by the lateral ligaments the primitive connective tissue becomes thicker than in the anterior and the posterior regions of the joint the primitive fibroblasts become arranged in parallel rows packed closely and are at first continuous with the cells comprising the menisci Older specimens reveal the gradual transformation of the ligaments until they assume adult features

The structural pattern of the various components of the medial ligament and their relation to the medial meniscus are factors of fundamental significance in the mechanism of production of certain lesions of the internal meniscus and of the medial ligament itself

FIBULAR COLLATERAL LIGAMENT (EXTERNAL LATERAL LIGAMENT)

It has been recorded in many of the current texts dealing with the development of the various structures of the knee joint that during the early stages of development the fibula articulates with the femur and that the fibula is excluded from the knee joint by the difference in the rate of growth of the tibia and the fibula In so doing the head and the styloid process of the fibula pull down with them a projection of the fibrous capsule and this becomes the deep portion of the external lateral ligament (short external ligament) The superficial portion or the long external lateral ligament, is believed to be the remnant of the tendon of the peroneus longus As noted previously these concepts are not substantiated by investigations conducted on the embryology of the knee joint The proximal tibiofibular joint develops as a separate articulation its development is similar to the femorotibial joint Moreover like the internal lateral ligament the external lateral ligament develops as a separate structure arising from the primitive tissue destined to form the adult fibrous capsule of the knee joint

The adult fibular collateral ligament consists of a deep and a superficial component (Fig 37) The deep portion is relatively

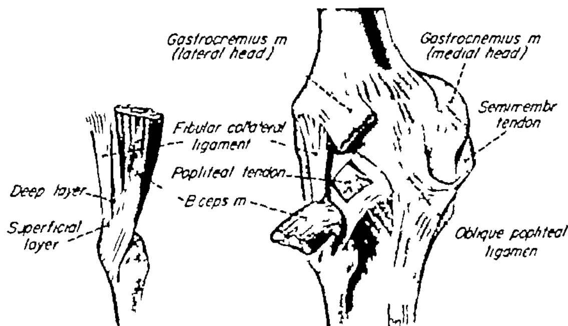


FIG 37 The fibular collateral ligament is separated from the periphery of the lateral meniscus by the popliteus tendon and its synovial sheath The ligament consists of a superficial and a deep portion Just proximal to the styloid process of the fibula the tendon of the biceps forms a spiral winding counter-clockwise around the superficial portion of the ligament so that it comes to lie between the two layers of the ligament

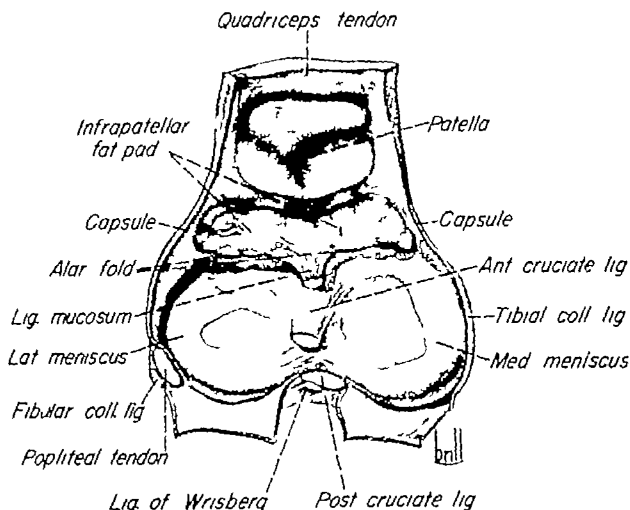


FIG 38 Superior surface of the tibia with patellar tendon attached Observe the relation of the anterior cruciate ligament to the menisci the ligamentum mucosum and the infrapatellar fat pad.

small and is attached above to the lateral epicondyle of the femur and below to the medial aspect of the upper surface of the head of the fibula and to the styloid process It is separated from the periphery of the lateral meniscus by the tendon of the popliteus muscle and its synovial sheath It is not attached to the lateral meniscus at any point Its posterior border is continuous with the fascia covering the popliteus muscle and contributes to the formation of the arcuate ligament The upper portion of the arcuate ligament together with the capsule is firmly adherent to the periphery of the posterior segment of the lateral meniscus the posterior surface of the ligament of Wrisberg (if present) and to the posterior surface of the posterior cruciate ligament The superficial component of the fibular collateral ligament is referred to as the long external ligament or the lateral ligament It is a stout fibrous cord It inserts above to the lateral epicondyle of the femur below it attaches to the upper surface of the head of the fibula lateral to the deep portion The two parts of the ligament can be separated readily by sharp dissection Just proximal to the styloid process of the fibula the tendon of the biceps femoris forms a spiral, winding counterclockwise around the superficial portion of the ligament so that the tendon eventually comes to occupy a position between the two layers of the ligament in turn, the ligament divides the tendon of the biceps femoris into a superficial and a deep layer The superficial lamina inserts

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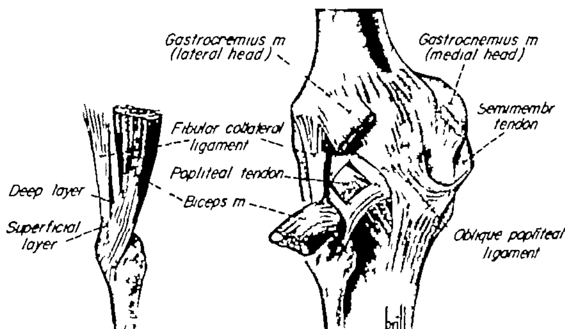


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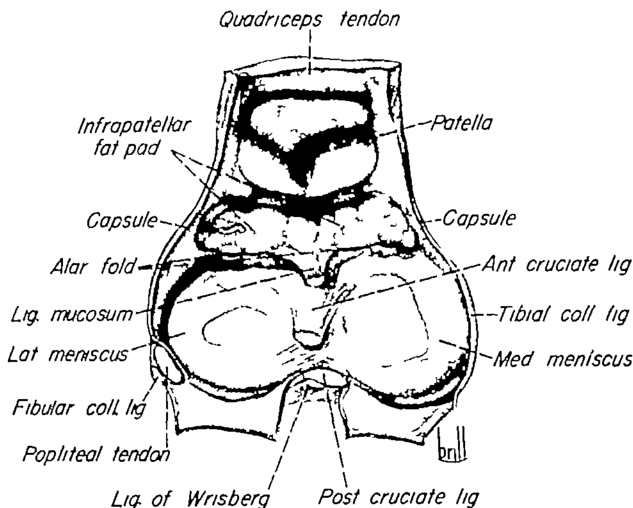


FIG 38 Superior surface of the tibia with patellar tendon attached. Observe the relation of the anterior cruciate ligament to the menisci, the ligamentum mucosum and the infrapatellar fat pad

small and is attached above to the lateral epicondyle of the femur and below to the medial aspect of the upper surface of the head of the fibula and to the styloid process It is separated from the periphery of the lateral meniscus by the tendon of the popliteus muscle and its synovial sheath it is not attached to the lateral meniscus at any point Its posterior border is continuous with the fascia covering the popliteus muscle and contributes to the formation of the arcuate ligament The upper portion of the arcuate ligament together with the capsule is firmly adherent to the periphery of the posterior segment of the lateral meniscus the posterior surface of the ligament of Wrisberg (if present) and to the posterior surface of the posterior cruciate ligament The superficial component of the fibular collateral ligament is referred to as the long external ligament or the lateral ligament, it is a stout fibrous cord It inserts above to the lateral epicondyle of the femur, below it attaches to the upper surface of the head of the fibula lateral to the deep portion The two parts of the ligament can be separated readily by sharp dissection Just proximal to the styloid process of the fibula the tendon of the biceps femoris forms a spiral, winding counterclockwise around the superficial portion of the ligament so that the tendon eventually comes to occupy a position between the two layers of the ligament in turn, the ligament divides the tendon of the biceps femoris into a superficial and a deep layer The superficial lamina inserts

into the lateral aspect of the head of the fibula, and its fibers continue distally fusing with the fibrous capsule of the proximal tibiofibular joint. The deep portion of the biceps tendon inserts into the head of the fibula between the superficial and the deep components of the collateral ligament

OBLIQUE POPLITEAL LIGAMENT (LIGAMENT OF WINSLOW)

Essentially this ligament is an expansion of some of the fibers of the tendon of the semimembranosus muscle directed proximally and laterally and extending from the posterior aspect of the medial condyle of the tibia to the outer epicondyle of the femur (Fig 32) Its fibers are interlacing and arranged in fasciculi between which are located apertures for the passage of vessels and nerves It is a dense flat, relatively broad structure forming the floor of the popliteal fossa and upon it lie the popliteal vessels

ARCUATE POPLITEAL LIGAMENT

Proximally this ligament is in relation to the posterolateral aspect of the lateral condyle of the femur here it blends with the oblique popliteal ligament beneath the lateral head of the gastrocnemius muscle It arches downward over the tendon of the popliteus muscle and its fibers converge toward the styloid process of the fibula where they insert in two distinct bands (Fig 32)

CRUCIATE LIGAMENTS

The bony configuration of the knee joint contributes little to the stability and the integrity of this articulation. As previously recorded the strength of the knee joint is dependent upon the integrity of the muscles which motorize it upon its intricate system of ligaments. It will be shown subsequently that the ligaments of the knee joint are second to the muscular apparatus in providing the normal stability of this joint Furthermore it will be shown that the functional mechanics of the numerous ligaments is such that they all work together as a single unit. This is particularly true of the collateral the cruciate and the capsular ligaments The tibial collateral ligament and the anterior cruciate ligament are most vulnerable to minor and severe trauma hence, lesions of these structures are encountered not infrequently

From a developmental viewpoint, the cruciate ligaments represent the collateral ligaments of two femorotibial joints It is generally accepted that they arise as intra articular structures and are discernible before the development of the capsule This observation fails to support Keith s conception that the cruciate ligaments are part of the posterior capsule and are displaced into the joint cavity during development by growth backward of the condyles of the femur They possess considerable strength and occupy a position in the middle of the articulation slightly more posterior than anterior Their position of attachment to the tibia is responsible for the designations anterior and posterior cruciate ligaments

Anterior Cruciate Ligament. This ligament is attached anteriorly to the nonarticular area of the upper end of the tibia just in front of the intercondyloid eminence and on a level with the anterior attachment of the outer meniscus (Fig 38) Occasionally it receives projection from one or both of the menisci It pursues a course directed upward backward and laterally and gains attachment to the posterior aspect of the inner surface of the lateral condyle of the femur Except for the posterior surface of the posterior attachment the ligament is enveloped completely by synovial membrane.

Posterior Cruciate Ligament. Posterior to the anterior cruciate ligament is located the posterior cruciate It is of greater strength than the anterior structure. It is attached to the posterior intercondyloid fossa of the tibia just behind the posterior horn of the medial meniscus with which it also fuses It then proceeds upward forward

and medially, crossing the anterior cruciate to be fixed to the anterior and the lateral aspects of the medial condyle of the femur (Fig 39) Generally, the posterior aspect of the cruciate ligament blends with the capsule, occasionally, a synovial recess may be found partially separating the two structures Moreover, it receives a slip from the posterior horn of the lateral meniscus The projection usually passes posterior to the cruciate ligament and gains attachment to the medial condyle of the femur it is known as the ligament of Wrisberg Occasionally, the slip passes anteriorly (ligament of Humphry) and in rare instances it separates into two slips, one passing anterior and the other posterior to the posterior cruciate ligament (Fig 40) The function of these structures will be discussed in the section on the mechanism of the knee joint

MENISCI OF THE KNEE JOINT

These are two crescentric disks triangular in cross section, each covering less than two thirds of the corresponding articular surface of the tibia upon which they rest (Fig 38) Their configuration deepens the articular surfaces of the tibial plateaus, and they consist of dense, tightly woven collagen fibers which are arranged more loosely at their extremities. The circumferential borders of each meniscus are convex and

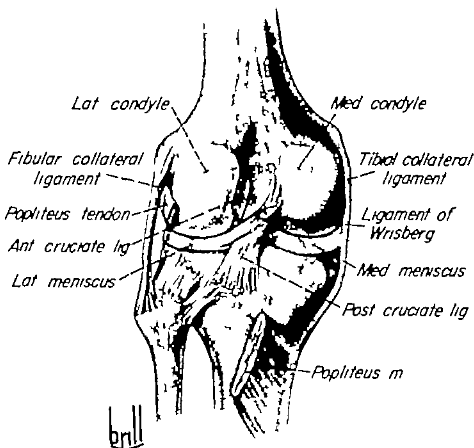


Fig 39 Posterior aspect of the stripped knee joint. Observe the relation of the posterior cruciate ligament to the medial meniscus, the anterior cruciate ligament to the medial meniscus, the posterior cruciate ligament to the ligament of Wrisberg

thick and loosely attached to the borders of the condyles of the tibia by the coronary ligaments and to the inner surface of the fibrous capsule of the joint except where the tendon of the popliteus is interposed between the capsule and the external meniscus The inner borders are free thin and concave Their superior surfaces are concave and articulate with the femoral condyles on the other hand the inferior surfaces are flat and articulate with the plateaus of the tibia In adults all unattached surfaces of the menisci are devoid of synovialis and are avascular except for a narrow zone adjacent to their points of attachment

Medial Meniscus The structure discloses a shape more oval than circular being nearly semicircular it is a segment of a larger circle than the lateral meniscus is Also its posterior portion is broader than the anterior the anterior cornu is thin and slightly pointed Both the anterior and the posterior cornua gain attachment by means of dense fibrous tissue to the anterior and the posterior regions of the nona areas of the upper end of the tib anterior cornu is attached firmly aforementioned nonarticular area terior to the anterior cornu of the meniscus and the anterior cruciate l (Fig 38) The broad attachment of terior cornu occupies a site betw tibial spine and the point of attach the posterior cruciate ligament Fr above description one notes that botl of the lateral meniscus are situated those of the medial meniscus Occa a synovial pouch is projected betw posterior cornu of the medial menis the posterior cruciate ligament I instances a reflection of synovialis tend behind the posterior cruciate l and at times also behind the poster ment of the meniscus

Three variations of the attachmen anterior cornu of the medial menis be found (Fig 41) (1) The anterio may have a single attachment to terior region of the nonarticular area

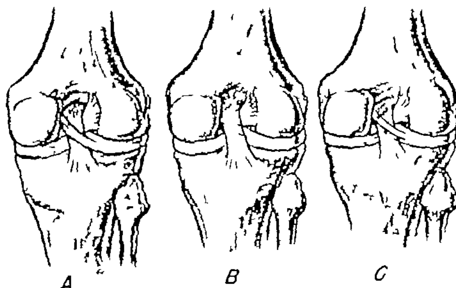


Fig 40 Different arrangements of slip or slips from the lateral meniscus in relation to the posterior cruciate ligament (A) two slips one passing anterior and the other posterior to the ligament (B) one slip passing anterior to the ligament (ligament of Humphry) (C) one slip passing posterior to the ligament (ligament of Wrisberg)

addition to the main site of attachment noted above, a transverse cord of fibrous tissue of varying length, designated as the transverse ligament may extend from the anterior cornu of the meniscus to the outer aspect of the anterior cornu of the lateral meniscus, occasionally, a pad of fat tissue is interposed between the transverse ligament and the tibia. (3) A second band of fibrous tissue may be found extending from the anterior cornu to the anterior cruciate ligament.

It was recorded previously that, except at the periphery of the anterior and the posterior cornua, the circumference of the medial meniscus blends with the fibrous joint capsule and fuses firmly with the oblique posterior fibers of the superficial portion of the tibial collateral ligament just posterior to its center The periphery of the anterior segment of the meniscus is attached loosely to the anterior portion of the ligament from which it can be detached readily by blunt dissection (Fig 35)

Lateral Meniscus. The shape of the lateral meniscus is nearly circular it forms a large segment of a small circle It covers more of the articular surface of the corresponding plateau of the tibia than the medial meniscus does (Fig 38) Both cornua are attached to the tibia The anterior one is attached in front of the intercondyloid eminence of the tibia behind and slightly lateral to the anterior cruciate ligament and behind the attachment of the anterior cornu of the medial meniscus, the posterior cornu inserts into the posterior region of the intercondyloid eminence of the tibia and in front of the posterior cornu of the medial meniscus Occasionally the anterior cornu gives off a small fibrous prolongation which continues to the anterior cruciate ligament another fasciculus varying in size, arising from the convex margin of the lateral meniscus extends to the anterior cornu of the medial meniscus This constitutes the transverse ligament The posterior cornu gives origin to a strong fasciculus which continues upward and medially behind the posterior cruciate ligament inserting into the medial condyle of the femur this constitutes the ligament of Wrisberg and was found in 53 per cent of the specimens studied This is a relatively strong ligament Usually it blends with the posterior cruciate ligament occasionally

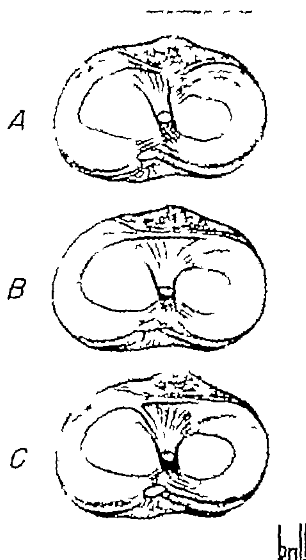


FIG 41 Three variations of the attachment of the anterior cornu of the medial meniscus. (A) It may have single attachment to the anterior region of the nonarticular area of the tibia. (B) In addition to the attachment noted above a transverse fibrous slip may extend from the anterior cornu of the meniscus to the anterior cornu of the lateral meniscus. (C) A second band may extend from the anterior cornu to the anterior cruciate ligament.

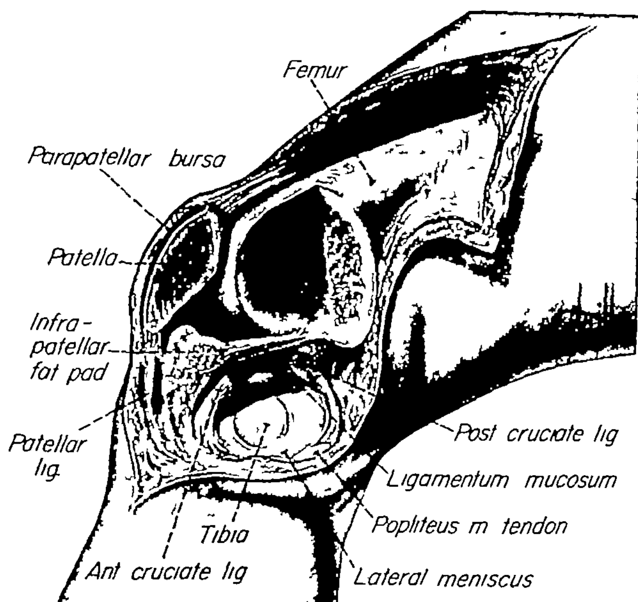


FIG 42 View of structures in the lateral compartment of the knee joint. The lateral femoral condyle has been removed

an interval of several millimeters may separate the two structures It is not invested by synovial membrane

In 20 per cent of the specimens a fasciculus arising from the posterior cornu extended upward and medially in front of the posterior cruciate ligament and like the ligament of Wrisberg became attached to the medial condyle of the femur this is the ligament of Humphry first described by George Murray Humphry in 1858 Generally it is a smaller structure than the posterior ligament (Wrisberg's ligament) and is covered by synovial membrane it blends with the posterior cruciate ligament

From the above description it becomes apparent that both cornua of the lateral meniscus are anchored firmly in addition its posterior segment is fixed to the arcuate ligament whose fibers blend with those of the fascia, covering the popliteus muscle Elsewhere the lateral meniscus is free for the tendon of the popliteus muscle which is invested in a synovial membrane separates it from the joint capsule and the deep portion of the fibular collateral ligament (Fig 38) The tendon of the popliteus muscle produces a well-defined oblique groove on the periphery of the external meniscus this region of the meniscus is the only portion

on the periphery of either meniscus which is in contact with synovial membrane Subsequently, it will be pointed out that the above relationship of the external meniscus to the cul-de-sac of synovialis covering the popliteus tendon may play a role in the formation of "cysts of the external meniscus" (Fig 42)

The aforementioned points of fixation of the lateral meniscus together with its relative degree of mobility, undoubtedly play a major role in the protection of the structure from injury, particularly during medial rotation of the fixed tibia in flexion When the motion is executed the popliteus muscle via the arcuate ligament draws backward the posterior segment of the lateral meniscus thereby preventing the structure from being crushed between the femoral condyle and tibial plateau The ligaments of Humphry and Wrisberg also act in backward displacement of the lateral meniscus

TRANSVERSE LIGAMENT

This structure comprises a fasciculus running from the periphery of the anterior convex portion of the lateral meniscus to the corresponding region of the medial meniscus (Fig 41)

CORONARY LIGAMENTS

These are fibrous prolongations of the fibrous capsule which connect the peripheries of the menisci with the adjacent margin of the head of the tibia.

SYNOVIAL MEMBRANE

The cavity of the knee joint is the largest in the body and is enclosed by the fibrous joint capsule which is lined by synovial

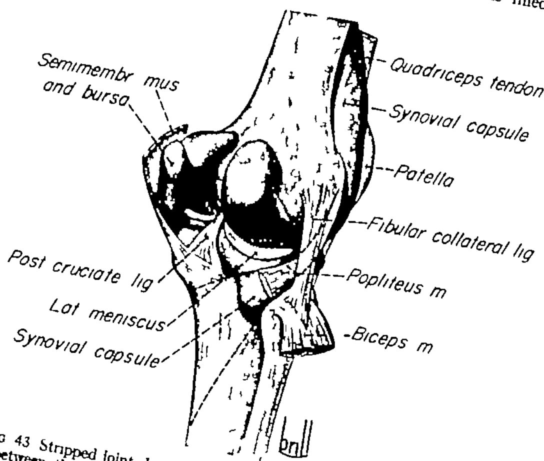


FIG 43 Stripped joint showing the synovial capsule The quadriceps pouch lies between the anterior surface of the femur and the quadriceps tendon The semimembranosus bursa in this specimen communicates with the joint cavity The popliteus tendon is separated from the lateral meniscus by a prolongation of the synovial capsule posteriorly

membrane (Fig 43) According to Mc Dermott the synovialis develops by re arrangement of the fibroblasts forming the inner surface of the fetal capsule of the joint and the most superficial cells of the un attached portions of the intra-articular structures namely the menisci the cruciate ligaments the ligament of Humphry and the infrapatellar fat pad Under the quadri ceps femoris muscle the synovialis extends upward a handbreadth above the upper pole of the patella to form the quadriceps pouch which rests on the anterior surface of the distal portion of the femur Between the femur and the synovial pouch is a loosely arranged layer of adipose tissue The upper pole of the pouch is supported during move ments of the knee joint by a small muscle the articularis genu, which arises from the anterior surface of the femur beneath the vastus intermedius and inserts into the prox imal portion of the synovial pouch Occa sionally the quadriceps pouch communi cates with a bursa lying between the femur and the tendon From either side of the patella the synovialis projects beneath the aponeurosis of the vasti muscles Anteriorly it is separated from the undersurface of the ligamentum patellae by a large pyramidal pad of fat the infrapatellar fat pad, which projects into the joint cavity and occupies the space from the lower border of the patella to the anterior border of the articu lar surface of the tibia. On either side of

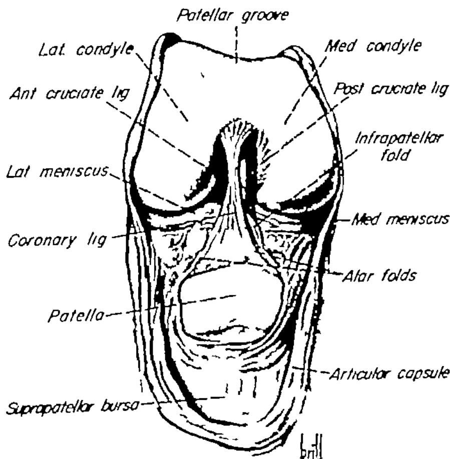


Fig 44 This specimen exhibits a well formed ligamentum mucosum formed by the convergence of the alar folds.

the patella close to the articular margins, the synovialis investing the infrapatellar fat pad falls into loose folds designated as alar folds, below, these converge to form a median fold, the ligamentum mucosum which extends to the anterior region of the intercondyloid fossa of the femur in relation to the anterior surfaces of both the anterior and the posterior cruciate ligaments (Fig 44) In many dissected specimens the alar folds were found to be demarcated poorly or were absent in the lower region of attachment of the ligamentum mucosum On the other hand, all knee joints revealed well formed plications of synovialis (alar folds) on either side of the patella From the inferior portions of the infrapatellar fat pad loose folds of synovial membrane and fat tissue are observed normally to cover the anterior portions of the semilunar cartilages. Fisher designated these processes semilunar processes of the infrapatellar fat pad or "semilunar pads " He further noted that in the terminal phase of extension (the screw home movement), the anterior portion of the inner condyle of the femur moves over the inner semilunar pad and not on the anterior segment of the inner meniscus The writer has confirmed this observation many times in the specimens studied Moreover in complete extension the semilunar pads, not the menisci, are compressed between the anterior portions of the condyles and the articular surfaces of the tibia

During flexion of the knee joint the ligamentum mucosum becomes taut and pulls the infrapatellar fat pad backward Some fibers of the articularis genu muscle continue downward and blend with the infrapatellar fat pad In complete extension these muscle fibers displace the pad of fat upward thereby preventing this structure

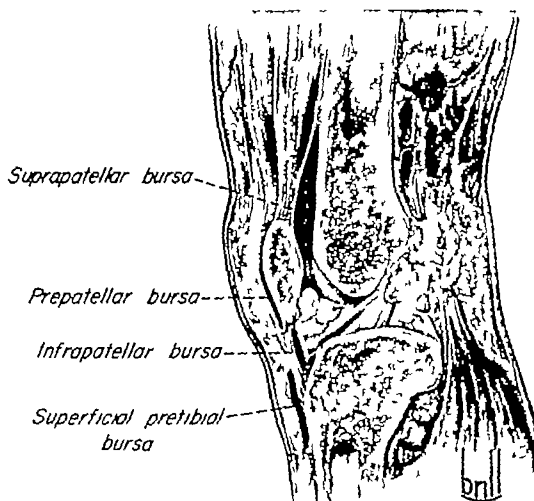


Fig 45 Bursae about the knee joint.

from being caught between the condyles of the femur and the tibial plateaus The same mechanism would tend to pull the semilunar cartilages forward

In the position they occupy in relation to the menisci, the semilunar pads are vulnerable to the same mechanisms of trauma that produce lesions of the menisci Lesions of *the semilunar processes must be considered* as factors responsible for internal derangement of the knee joint

Before the period of the erect position is assumed all unattached surfaces of the menisci and the cruciate ligaments are covered by synovial membrane In the adult the superior and the inferior surfaces of the menisci are devoid of synovialis except at their site of attachment to the capsule Unattached surfaces of both cruciate ligaments are invested with synovialis A constant defect in the fibrous capsule is created by the passage of the tendon of the popliteus muscle which forms an oblique indentation or groove on the posterior aspect of the lateral meniscus the tendon is ensheathed in synovial membrane which forms a small cul-de-sac in this region Two prolongations *of the synovial membrane in the form of* pouches are found constantly on the back of the knee joint, one on each side between the medial and the lateral condyles of the femur and the tendons of origin of the gastrocnemius muscle

BURSAE

Numerous bursae are present in relation to the knee joint (Fig 45) Anteriorly there are 4 bursae One is situated between the

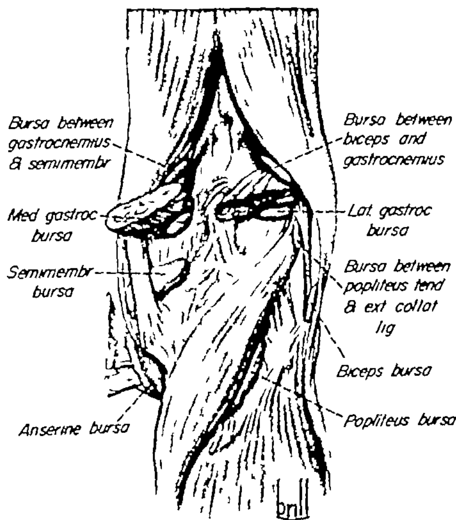
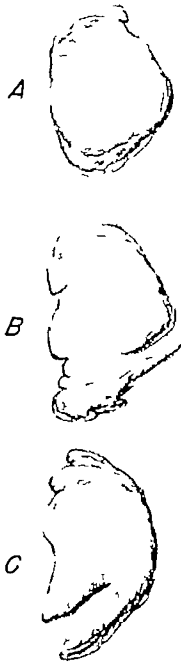


FIG. 45 (*Continued*) Bursae about the knee joint

Fig. 46 Types of congenital discoid menisci according to Smillie's classification drawn from specimens obtained at operation. (A) Primitive disk. No evidence of dissolution of the central portion of the disk the peripheries and the central area exhibit considerable thickness. (B) The central margin is notched and thinner than the corresponding region in the primitive disk also, the central region is less massive. (C) This approaches the configuration of the normal structure more closely than the other two forms There is an abnormal increase in breadth of the central portion of the structure as compared with the normal Drawn from specimens (Figs 123, 125, 127)



skin and the anterior surface of the patella (prepatellar bursa) a smaller bursa is present between the ligamentum patellae and the anterior surface of the upper region of the tibia The third bursa lies between the skin and the distal portion of the tuberosity of the tibia the fourth is located between the undersurface of the tendon of the quadriceps femoris and the anterior surface of the distal portion of the femur As a rule, this last bursa communicates with the cavity of the knee joint Laterally 4 bursae are usually demonstrable One lies between the capsule of the joint and the lateral head of the gastrocnemius, frequently this bursa communicates with the articular cavity The second is situated between the tendon of the biceps femoris and the fibular collateral ligament, a third bursa is present between the lateral condyle of the femur and the tendon of the popliteus and the fourth lies between the tendon of the popliteus and the fibular collateral ligament Medially 4 bursae are usually encountered The first occupies a position between the capsule and the medial head of the gastrocnemius this frequently communicates with the joint and also extends between the tendon of the semimembranosus and the tendon of origin of the medial head of the gastrocnemius. Another is located between the tendons of the sartorius, the gracilis the semitendinosus and the outer surface of the tibial collateral ligament A third is found between the head of the tibia and the under surface of the tendon of the semimembranosus this sends a prolongation between the tendon of the semimembranosus and the deep surface of the tibial collateral ligament. A fourth is present occasionally between the tendons of the semitendinosus and the semimembranosus

Discoid Menisci

Study of the development of the knee joint discloses that discoid menisci represent a failure of interchondral disks to assume the characteristic features of the adult structure

It is a clinical fact that congenital discoid menisci are encountered most frequently by

far in the lateral femorotibial component of the knee joint Although medial congenital discoid menisci have been recorded in the literature they are exceedingly rare Also bilateral discoid menisci have been reported

From the middle of the fourth month of antenatal life to birth the menisci cover the greater part of the adjacent articular surfaces of the tibia and the femur the medial meniscus allows a larger area of con tact between the condyle of the femur and the tibia than the lateral meni cus does This relationship does not alter in any appreciable degree until the child begins to assume the erect posture Then the area of contact between the femoral condyles and the tibia increases progressively in size until it assumes the dimensions observed in the adult knee joint.

Study of the gross specimens obtained at operation and at postmortem reveals that arrest in the formation of the lateral meniscus at different stages of development re sults in numerous varieties of congenital discoid menisci Smillie, in his comprehen sive work *Injuries of the Knee Joint* grouped all these varieties into three categories the primitive the intermediate and the infantile type Each type represents a stage at which the normal development of the meniscus has been terminated It be comes apparent that numerous variations are possible however for practical pur poses all anomalies encountered can be grouped in the aforementioned classifica tion.

PRIMITIVE DISK

This disk represents the earliest stage at which interruption of the natural development of the meniscus occurs in antenatal life (Fig 46 A) Dissolution of the central portion of the interchondral disk fails to occur or occurs only in part never suffi ciently to allow the formation of a structure which possesses any resemblance to a nor mal meniscus The thickness and the breadth of the interchondral plate depend upon the stage at which arrest of the normal processes of development occurs the thick ness of the periphery of the disk does not differ from that of a normal meniscus Therefore it becomes obvious that the earlier the interruption of development oc curs the greater will be the breadth of the disk and the greater will be the thickness of its central portion

INTERMEDIATE DISK

Arrest of development of the meniscus just beyond the stage responsible for the formation of a primitive type of disk re sults in the formation of the intermediate type (Fig 46 B) Its features are less distinctive than those of the primitive type Its central portion is relatively thin and its central border may be transparent, a struc tural characteristic not observed in the primitive type Its total mass is consider ably less than that of the primitive variety Another constant configuration of this struc ture is the presence of two indentations on its central border one is situated imme diately in front of the posterior attachment of the disk and the other directly behind the anterior central attachment. Between the two indentations the central margin bulges toward the center of the joint the extent of the central projection varies considerably in the different specimens

INFANTILE DISK

This structure represents a stage in the arrest of development not far from the for mation of a normal meniscus (Fig 46 C) In many respects it demonstrates features resembling closely those of a fully devel oped meniscus noted at birth. Its chief dif ferentiating feature is an abnormal increase in breadth of the central portion of the meniscus In a normally developed lateral meniscus the anterior the posterior and the central portions are all of the same width As pointed out by Smillie not infrequently some slight increase in the breadth of the central portion is encountered however

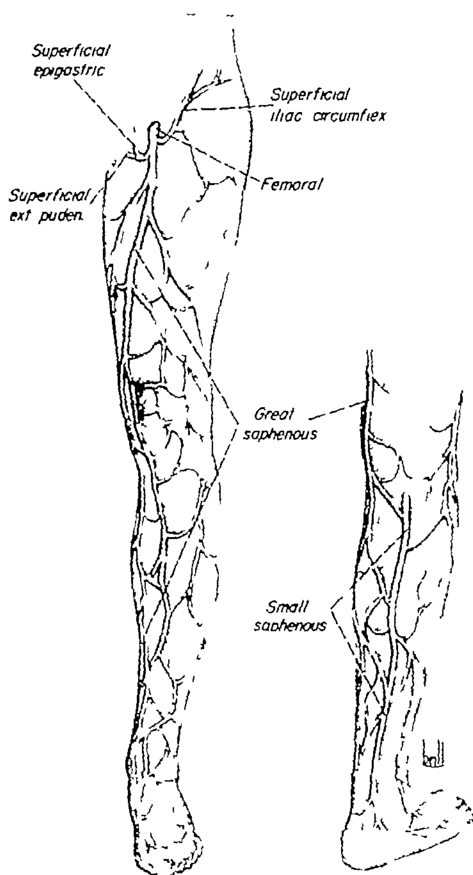


Fig 47 Superficial veins of the extremity

this is considered to be within normal limits Abnormal increase in the breadth of the central segment must be considered as an interruption in the natural process of development

Vessels and Nerves

Superficial Vessels

A rich network of small veins lies in the superficial fascia of the thigh and the lower leg (*Fig 47*) From this intricate network two large trunks emerge into which all the smaller vessels empty The great saphenous vein is the larger of the two collecting vessels it takes origin on the anteromedial aspect of the foot from the dorsal venous arch and pursues a course upward in front of the medial malleolus and slightly posterior to the medial margin of the tibia. It continues upward behind the medial epicondyle of the femur, then passes to the anteromedial position in the thigh to a point approximately 3 cm below the inguinal ligament Here it passes through a defect in the fascia lata (fossa ovalis) and ends in the femoral vein In its ascent in the lower leg it is in relation with the saphenous nerve which pierces the deep fascia just below the knee joint to occupy a more superficial position This vein may have as many as 10 to 20 valves

The small saphenous vein arises from the lateral portion of the venous arch on the dorsum of the foot behind the external malleolus At first it continues upward along the lateral border of the tendo calcaneus then crosses it to occupy a position in the center of the posterior surface of the calf in relation with the sural nerve (short saphenous nerve) At the distal end of the popliteal fossa it perforates the deep fascia and between the two heads of the gastrocnemius muscle terminates in the popliteal vein It possesses from 9 to 12 valves.

Deep Vessels

Popliteal Vein. At the distal border of the popliteus muscle the anterior and the posterior tibial veins join to form the popliteal vein, which continues upward through the popliteal fossa as far as the aperture in the adductor magnus muscle. Here it becomes the femoral vein At the beginning of its course the vein lies on the medial side of the femoral artery between the two heads of the gastrocnemius it occupies a position superficial to the artery, crossing it obliquely and finally in the upper region of the popliteal fossa it lies close to its lateral side Into the popliteal vein empty the small saphenous vein the accessory popliteal veins and the veins accompanying the corresponding branches of the popliteal arch Its fascial sheath blends with that of the femoral artery It contains from 2 to 4 valves Superficial to the vein is the tibial nerve (internal popliteal) which in its downward course first lies lateral then posterior and finally medial to the vein

Femoral Vein. This vein begins as a continuation of the popliteal vein at the opening in the adductor magnus muscle It extends upward to the inguinal ligament Throughout its course it lies in relation to the femoral artery Its lower portion lies posterior and lateral to the artery at the apex of the femoral triangle it is posterior to it From this point it assumes gradually a medial position to the artery so that at the inguinal ligament it lies directly to its medial side and on the same plane The femoral vein possesses from 3 to 5 valves (Fig 48)

Deep Femoral Vein. The tributaries corresponding to the perforating branches of the profunda artery drain into the deep femoral vein which in turn empties into the femoral vein Both the medial and the lateral femoral circumflex veins open into the profunda femoris veins occasionally they flow directly into the femoral vein

Femoral Artery The femoral vein the femoral artery and the femoral nerve in the order noted from medial to lateral side pass beneath the inguinal ligament to appear on the anterior aspect of the thigh Both the artery and the vein pass imme

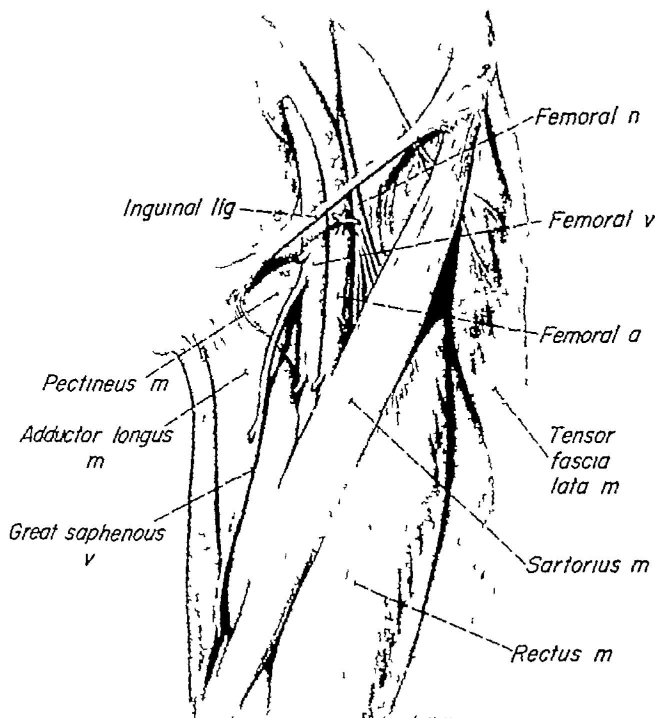


Fig 48 Anatomic relations of the femoral vein the femoral artery and the femoral nerve in the femoral triangle

diately behind the inguinal ligament in a fascial compartment which is formed by a continuation distally of the transversalis fascia in front and the iliac fascia behind the femoral vessels This structure (about 4 cm long) is called the femoral sheath and is shaped like a funnel its wide end being directed upward and its distal end blending with the fascial covering of the vessels The femoral sheath is subdivided into three separate compartments by two vertical fibrous septa The medial one (femoral canal) con

tains no significant structures being occupied by loose areolar tissue and a lymph node the intermediate compartment contains the femoral vein and the lateral the *femoral artery The femoral nerve lies* outside the femoral sheath behind the iliac fascia it passes downward on the anterior surface of the iliopsoas muscle occupying the same fascia compartment as the muscle (Fig 48)

The femoral artery is the continuation of *the external iliac artery*, it begins just behind the inguinal ligament and passes distally along the anterior and the medial aspects of the thigh as far as the aperture in the adductor magnus muscle at the junction of the middle and the lower thirds of the *thigh Here it passes through the hiatus to* reach the posterior aspect of the distal third of the thigh, where it becomes the popliteal artery In the extreme upper end of the thigh immediately below the inguinal ligament the first 4 cm. of femoral artery lie in the femoral sheath in the upper third of the thigh it occupies a position in the femoral triangle in relation with the femoral vein and the femoral nerve the distal end of the artery lies in the adductor canal The adductor canal is an interval between the quadriceps muscles and the adductor *muscles which is covered by an aponeu*rotic prolongation extending from the vastus medialis to the adductor longus and the adductor magnus muscles Immediately anterior to this fibrous sheath lies the sartorius muscle With the leg in a position of slight abduction and flexion the course of the artery follows a line extending from a point midway between the symphysis pubis and the anterior spine of the ilium to the adductor tubercle *In the upper part* of the thigh the artery occupies a position in front of the hip joint

Immediately below the inguinal ligament the femoral artery gives off four small branches which supply the lower part of the abdomen and the genitals these are the superficial epigastric the superficial iliac circumflex, the superficial external pudendal and the deep external pudendal arteries Also in this region it gives off two larger branches the medial and the lateral circum*flex* arteries, which encircle the extremity completely and anastomose with each other and other vessels situated in the proximal *portion of the extremity These last two* arteries mentioned may arise from the profunda femoris

The profunda femoris (deep femoral artery) is a relatively large vessel, it takes origin from the lateral and the posterior aspects of the femoral artery from 4 to 6 cm. distal to the inguinal ligament It continues distally and posteriorly first lying lateral to the femoral artery then posterior *to it close to the medial* margin of the femur It may pass in front of or behind the adductor longus muscle and in the distal third of the thigh it terminates in a small branch which, after piercing the adductor magnus muscle terminates in the hamstring muscles Four perforating branches are given off by the profunda femoris artery the fourth comprises the termination of the artery They are designated perforating ar*teries because they perforate the* tendinous insertion of the adductor muscle in order to reach the posterior region of the thigh passing in close relation to the linea aspera of the femur through aponeurotic openings in the muscle The most proximal branch takes origin from the profunda femoris above the adductor brevis muscle the intermediate branch in front of the muscle and the third branch just distal to it As noted above the fourth branch is *really* the termination of the artery All four perforating vessels form anastomosing loops with each other on the posterior surface of the adductor magnus muscle furthermore they anastomose above with the circumflex and the gluteal arteries and below with *the* genicular and the muscular *branches of the popliteal* artery

Popliteal Artery The popliteal artery begins at *the hiatus in the adductor* magnus

muscle It is a continuation of the femoral artery and terminates at the lower border of the popliteus muscle by dividing into the anterior and the posterior tibial arteries (Fig 49) It traverses the popliteal fossa, in which it occupies a deep berth In some instances it divides into its terminal branches at the level of the knee joint the anterior tibial continues distally in front of the popliteus muscle

Directly in front of the artery from above downward are located the popliteal surface

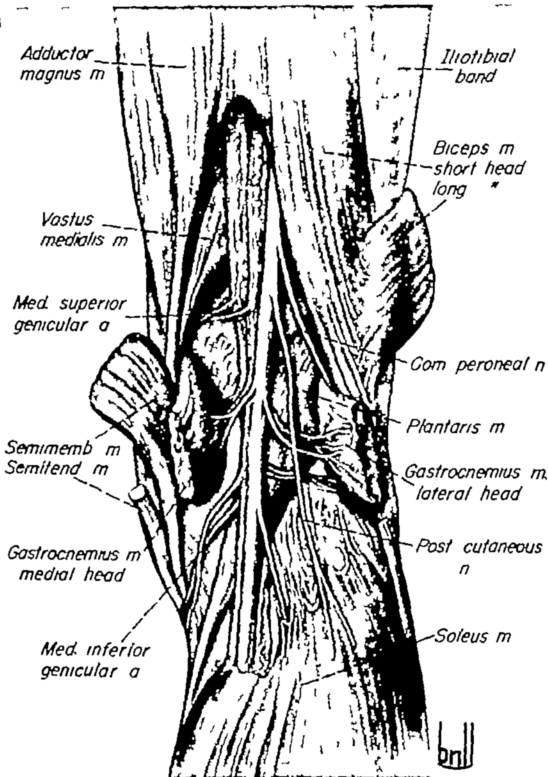


FIG 49 Anatomic relation of the vessels and the nerves in the popliteal fossa

of the femur, the posterior capsule of the knee joint and the fascial covering of the popliteal muscle. Posteriorly, the inner portion of the semimembranosus muscle overlaps the upper part of the artery and the distal segment of the vessel is covered completely by the inner portion of gastrocnemius and the plantaris muscles. The middle part of the artery is covered with much areolar tissue fat and skin and it is crossed by the tibial nerve and the popliteal vein as they pursue a course downward from the lateral to the medial side the vein being situated between the nerve and the artery Proximally on the lateral aspect of the artery are situated the popliteal vein, the tibial nerve, the biceps femoris muscle and the lateral condyle of the femur in the order noted from medial to lateral side distally there are the plantaris and the lateral head of the gastrocnemius muscles On the medial aspect, proximally are located the medial condyle of the femur and the semimembranosus muscle, distally there are the medial head of the gastrocnemius muscle and the tibial nerve The popliteal artery gives off the following branches the sural and two or three superior muscular branches the cutaneous the medial superior genicular, the lateral superior genicular, the middle genicular the medial inferior genicular and the lateral inferior genicular

Arterial Anastomosis Around the Knee Joint

A rich arterial rete is formed around the knee joint chiefly by the genicular arteries and the anterior recurrent tibial artery

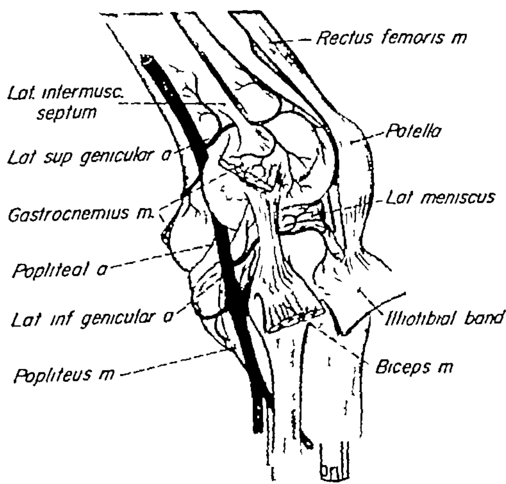


Fig 50 Arterial anastomosis around the knee joint lateral side

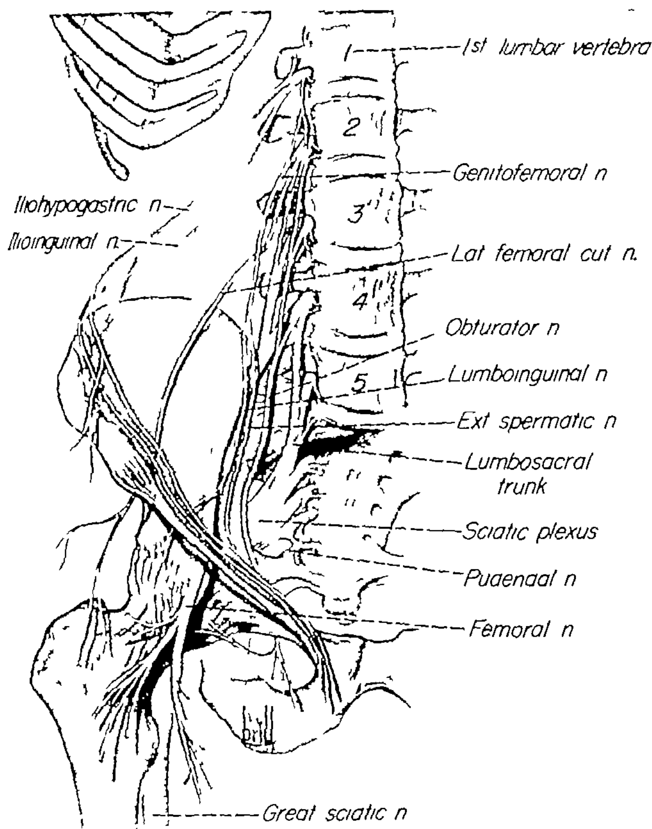


FIG 51 Origin of the lateral femoral cutaneous nerve of the thigh the obturator nerve, the femoral nerve and the sciatic nerve

(Figs 36 and 50) Two distinct anastomoses can be identified a superficial and a deep In the region of the upper border of the patella the superficial plexus or rete lies among the superficial fibers of the quadriceps muscle and comprises essentially a distinct vascular arch in this region Below the patella two similar arches are found beneath the ligamentum patellae in the loose fatty tissue situated in this region The deep

anastomosis comprises an intricate network of vessels located on the lower end of the femur and the upper end of the tibia sending branches to the contiguous bones and into the joint Chiefly concerned with the formation of the deep plexus are the four genicular arteries, the highest genicular (genu suprema) the descending branch of the lateral femoral circumflex and the anterior recurrent tibial The middle genicular artery (azygos) is smaller than the other four genicular arteries, it arises from the posterior aspect of the popliteal artery and together with the articular branch of the obturator nerve pierces the popliteal ligament to gain entrance into the knee joint It is distributed to the synovialis lining the joint the alar folds and the cruciate ligaments

POPLITEAL FOSSA

Knowledge of the anatomic positions of the structures found in the popliteal fossa is essential to surgeons performing operative

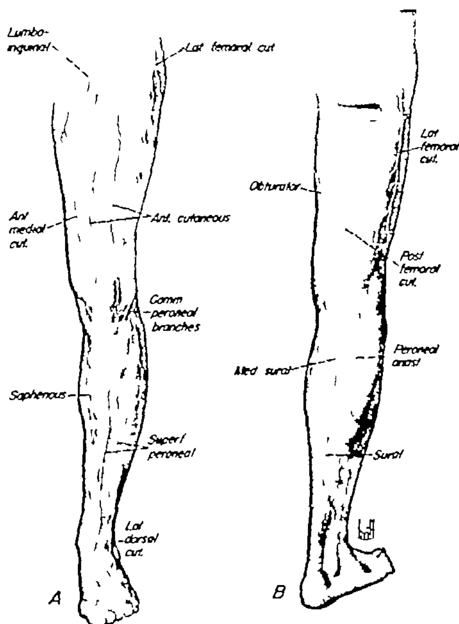


FIG. 52 Cutaneous nerves of the lower extremity (A) anterior view (B) posterior view

procedures on the posterior aspect of the knee joint (Fig 49) As will be shown later, many pathologic processes may arise in the region, necessitating surgical intervention

The muscles crossing the posterior aspect of the knee joint form the boundaries of the fossa which is lozenge shaped On the medial side above it is bordered by the semitendinosus and the semimembranosus muscles, below by the inner head of the gastrocnemius muscle The lateral boundary comprises, above, the biceps femoris muscle and, below the plantaris and the outer head of the gastrocnemius muscles Anteriorly the floor of the fossa comprises from above downward, the popliteal surface of the femur the oblique popliteal ligament, the upper end of the tibia and the fascial covering of the popliteus muscle Posteriorly the roof of the fossa is formed by the fascia lata.

The structures of greatest importance contained in the popliteal fossa are the popliteal artery and the popliteal vein and the tibial and the common peroneal nerves Of lesser importance are the articular branch of the obturator nerve the posterior femoral cutaneous nerve the termination of the small saphenous vein fat and several small lymph nodes. Lying directly on the floor of the fossa are the popliteal artery and the vein In the upper one half of fossa the vein lies lateral to the artery it then crosses the artery and in the lower one half it is found on the medial side of the artery Occasionally, two veins may be present in such instances the artery occupies a position between the two veins In the fossa the popliteal artery gives off the genicular branches which leave at right angles to the mother vessel. The tibial nerve lies under the deep fascia and pursues a course from above downward through the center of the fossa crossing the popliteal artery and the popliteal vein posteriorly from a lateral to a medial position The common peroneal nerve traverses the lateral side of the fossa under cover of the medial border, the biceps femoris muscle above and its tendon below In addition to the tibial and the common peroneal nerves the articular branch of obturator nerve is found in the fossa, occasionally it is absent It enters the fossa upon the popliteal artery, to which it gives filaments, and descends as far as the oblique popliteal ligament in the back of the knee joint, it pierces this ligament to gain entrance into the joint cavity where it supplies the synovial membrane (Figs 51 and 52)

Ossification

The osseous nucleus of the distal epiphysis of the femur is, as a rule, demonstrable at birth union of the epiphysis with the diaphysis usually occurs at the nineteenth year The appearance of the bony center of the patella varies greatly In females it generally appears in the fourth or the fifth year In some children it may appear during the first year in others not until puberty Not infrequently more than one center of ossification is present Ossification of the sesamoid bone of the outer head of the gastrocnemius muscle known as the fabella usually is delayed until puberty It is present in approximately 25 per cent of adult knees It may be bilateral

At birth or 2 or 3 weeks after, the nucleus of the upper end of the tibia is demonstrable It fuses with the diaphysis between the sixteenth and the twentieth years The nucleus for the proximal epiphysis of the fibula makes its appearance during the third or the fourth year it joins the shaft between the twentieth and twenty fifth years

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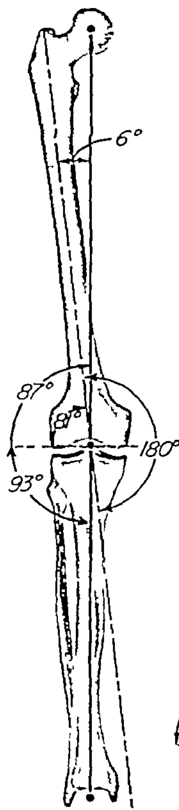
Mechanics of the Knee Joint

With the assumption of the erect posture many changes were necessary in the configuration and the mechanics of the knee joint. These alterations are reflected in the statics and the dynamics of this articulation The fact that dysfunction in the quadriceps apparatus is precipitated so readily by even minor injuries is a strong argument favoring the *premise* that the function of the quadriceps muscle in man is a recent acquisition Furthermore, the human knee joint finds itself in a vulnerable position and frequently is subjected to direct trauma and extraordinary torsional and bending stresses These forces give rise to specific injuries of the osseous elements and the ligamentous structures of the joint. Knowledge of the normal mechanics of the knee joint is essential in order to comprehend the pathomechanics producing the numerous and the varied lesions of the components of this articulation

AXIS OF THE KNEE JOINT

The mechanical axis of the femur does not coincide with its anatomic axis. This discrepancy is brought about by the position of the femoral neck in relation to the shaft which forms an angle of 120° to 135° with the femoral shaft. The mechanical axis corresponds to a line traversing the center of the hip joint and the center of the knee joint, forming an angle of from 6° to 9° with the axis of the shaft of the femur (Fig 53) In the erect position a transverse axis through the knee joints lies in the true horizontal plane this horizontal axis forms an angle of 87° with the mechanical axis of the femur and an angle of 81° with its anatomic axis (Fig 53) If the 87° which correspond to the angle between the transverse axis of the knee joint and the mechanical axis of the femur are subtracted from 180°, a supplementary angle of 93° remains which is the angle the mechanical axis makes with the transverse axis of the knee joint below the horizontal axis The normal deviation from the center of the knee is between 10° and 12°, corresponding to the axial deviation between the tibia and the femur The angle varies slightly in normal extremities and greatly in certain pathologic conditions as in genu varum and genu valgum Figure 54 shows that the mechanical axis of the femur is displaced further outward as the angle of abduction decreases and is displaced further inward as the angle increases According to Steindler Mikulicz noted that of 200 cases studied, 58 per cent revealed that the mechanical axis of the femur passed through the center of the joint, in the remaining 42 per cent the line deviated to the median side less than 1 cm in 87 5 per cent and more than 1 cm in 12 5 per cent Although these figures may vary in normal individuals, arbitrarily any deviation of the mechanical axis of the femur of 2.5 cm or more from the center of the knee joint in either direction must be considered abnormal

Displacement of the mechanical axis to either side of the center of the knee joints in excess of 2.5 cm produces increased abnormal longitudinal stresses on some of the bony elements of the articulation and stretching of the soft tissue structures on the same side. In genu varum longitudinal



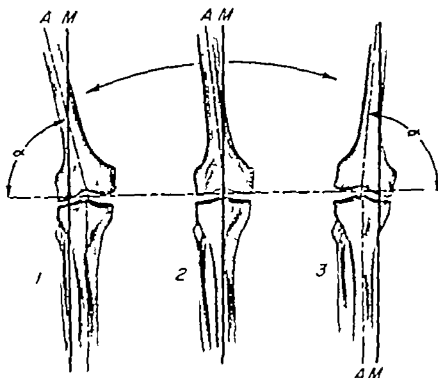
stresses are accentuated on the inner condyle of the femur and the inner articulating surface of the tibia and the capsule and the fibular collateral ligament on the lateral aspect of the knee joint are unduly stretched the reverse is true in genu valgum

STATICS OF THE KNEE JOINT

Examination of the lower extremities in the erect position with the knees extended discloses that the transverse axis passing through the condyles of the femora lies in a true frontal plane this is also true of a similar axis passing through both hip joints.

FIG 53 (*Left*) Anatomic axis of the femur mechanical axis of the femur transverse axis of the knee joint and mechanical axis of the leg (Redrawn from Steindler Mechanics of Normal Locomotion in Man)

FIG 54 (*Bottom*) The solid line represents the mechanical axis of the femur Note that as the angle of abduction decreases the mechanical axis is displaced further outward and as the angle increases the axis is displaced further inward. (1) Genu valgum the mechanical axis falls on the outer side of the center of the knee joint. (2) In the normal joint the mechanical axis passes through the center of the joint. (3) Genu varum the axis falls to the inner side of the center



However, the transverse axes of the necks of the femora are diverted forward by the normal position of anteversion of the necks in relation to the femoral shafts It becomes apparent that in order for the proximal and the distal ends of the femur to be in a strictly frontal plane, the shaft of the femur must undergo some inward torsion to compensate for the forward twist of the neck of the femur this torsion of the femur is approximately 25°

A similar relationship exists between the knee joint and the ankle joint In the latter the transverse axis courses obliquely from outward and backward to forward and inward Outward torsion of the lower portion of the tibia is responsible for the deflection of the axis of the ankle joint Furthermore, this deviation places the external malleolus of the ankle slightly behind the internal malleolus. The outward twist of the tibia is approximately 30° As a result of the aforementioned deflection of the transverse axis of the neck of the femur and of the ankle joint, the knee joint which lies between the two occupies a position of 25° of internal rotation in relation to the femoral neck and from 20 to 30° internal rotation in relation to the transverse axis of the distal end of the tibia.

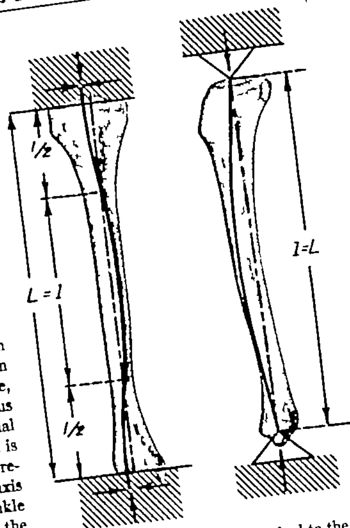


Fig 55 Column theory applied to the tibia. Frontal plane, $l = L/2$ Sagittal plane, $l = L$ (Redrawn from Steindler Mechanics of Normal Locomotion in Man)

STRESS AND STRAINS ACTING ON THE TIBIA

As pointed out by Steindler the tibia in the frontal plane approaches closely a column fixed above and below, since no movements at the knee joint are possible in this plane. The maximum bending stresses act at the middle of the shaft, while minimum bending stresses act at the intersections of the curves (Fig 55) In a measure these forces are influenced by the normal deviation of the knee joint which causes the load to fall lateral to the axis of the tibia and also by the lateral position of the fibula which affords further support to the tibia

In the sagittal plane the tibia is similar to a column hinged at both ends in which the maximum bending stresses are operative at the middle of the shaft and the maximum shearing forces at the ends

As previously noted with the knee extended the transverse axis of the knee joint is rotated inward from 20° to 30 in relation to the axis of the ankle joint This results in a torque outward of the lower end of the tibia

Steindler further recorded that in the frontal plane the inclination of the axis of the femur to that of the tibia produces a horizontal gravital component with bending and shearing stresses which are maximal at the joint and are resisted by ligamentous tension Also that similar bending

forces develop in the sagittal plane in abnormal situations as with tibia recurvata and patella alta

DYNAMICS OF THE KNEE JOINT

The knee joint possesses features characteristic of both the ginglymus (hinge joint) and trochoid (pivot joint) articulations. Essentially, it is capable of flexion and extension in the sagittal plane and, in certain positions of the joint of internal and external rotation The latter movements can be effected only when the knee joint is in certain degrees of flexion no rotation is possible with the knee in the fully extended position Movement in the sagittal plane is not only a true rolling motion on a transverse axis but also discloses a certain amount of gliding motion of the articular surfaces upon each other This is borne out by the marked incongruity that is demonstrable between the articular surfaces of the femoral condyles and the tibial plateau The menisci partially compensate for the incongruity by occupying a position between the articulating surfaces to a lesser degree further compensation is provided by the infrapatellar fat pad and the synovial folds As will be shown subsequently the menisci together with the collateral ligaments the cruciate ligaments and the patellar retinacula play a part in the stability of the knee joint

The natural deflection outward of the tibia on the femur at the knee joint permits greater weight bearing stresses on the outer femoral condyle than the inner but because the medial condyle of the femur is prolonged further forward than the lateral the vertical axis of rotation falls in a plane nearer the medial condyle During rotary movements the medial condyles describe a smaller arc than the lateral which must possess more freedom of motion and are less vulnerable to crushing forces during rotary movements

That the knee joint is not a true ginglymus joint is further demonstrated by the configuration of the condyles of the femur Both condyles are prolonged posteriorly in the form of massive rollers, being separated by the intercondyloid fossa as they continue posteriorly they diverge slightly The lateral condyle is broader both in the anteroposterior and the transverse planes than the medial the latter projects distally to a level slightly lower than the lateral condyle when the femur is held in a strictly perpendicular plane The natural deviation of the knee joint compensates for this difference so that when the erect position is assumed and the knee joint is extended fully both condyles lie in a true transverse plane The sagittal curves of both the medial and the lateral condyles form circles whose radii become progressively smaller forming a spiral curve It has been estimated that the ratio of the radius between the foremost and the hindmost portions of the curve is from 9 to 5 The radii of the curve of the lateral condyle are longer than those of the medial It becomes obvious that during flexion and extension of the knee joint the center of motion is not in a fixed transverse plane but is constantly changing The points of contact between the tibia and the femur in varying degrees of flexion have been demonstrated by roentgenograms (Zuppinger) and the angles of flexion corresponding to these contact areas were calculated by Fischer

MOVEMENTS OF THE KNEE JOINT

Analysis of the movements of the knee joint with the tibia fixed reveals that with the joint in full extension no rotary motion is possible During the first 20° of flexion the movement is strictly a rocking motion equidistant points on the articular surfaces of the condyles of the femur contact equidistant points on the tibial plateaus After 20° of flexion the movement becomes a gliding motion the femoral condyles now

glide over a small circumscribed portion of the surface of the tibia The transition from one form of motion to the other is gradual but progressive, until the gliding form replaces the rocking element completely The two types of motion described conform to the functional demands made on this articulation The rocking motion demonstrable in the first 20° of flexion meets the requirements for stability, beyond this first phase the joint unwinds, becoming more relaxed in order to permit axial rotation This last phase of movement is made possible by the progressively diminishing size of the posterior portions of the condyles of the femur and the relaxation of some and the decrease in tautness of other supporting ligaments. The configuration of the bony elements of the knee joint and the tenseness of its supporting ligaments allow no rotary motion in the extended and the hyperextended positions When flexion is initiated the fibular collateral ligament relaxes and the tibial collateral and the cruciate ligaments become less taut, hence allowing rotary movements As will be noted subsequently, the amount of axial rotation increases progressively varying in different joints, at 90° of flexion rotation ranged from 5° to 31° In complete flexion rotation is decreased, in this position the cruciate ligaments are tense Moreover with increased flexion the demands of weight bearing become increasingly less hence the gliding mechanism is well adapted for this stage of movement.

During flexion and extension the menisci maintain contact with the head of the tibia however they do migrate slightly forward in full extension and backward in full flexion In advanced flexion only a small area of the posterior portion of the condyles of the femur remain in contact with the menisci This area increases progressively in size as the degree of extension becomes greater It will also be shown that during flexion and extension the range of excursion of the internal meniscus is less than that of the external the former being firmly anchored to the capsule and the tibial collateral ligament at a point just posterior to its center This greater freedom of the external meniscus is responsible for making it less vulnerable to injury than the inner meniscus during forceful rotary movements of the joint When the extended knee executes the "screw home movement, the posterior portion of the outer condyle of the femur rotates forward and outward, pulling in its wake the posterior horn of the external meniscus As noted by Keith, repetition of this maneuver might tear the meniscus from its posterior capsular attachment, however, this is prevented by the stout fibrous attachment between the posterior cruciate ligament and the posterior horn of the external meniscus (ligament of Wrisberg)

Because of the difference in the configuration of the femoral condyles, the longitudinal axis of rotation passes through the medial condyle Inspection of the articular surfaces of the condyles discloses that the posterior two thirds of both condyles are parallel with one another However, the anterior one third of the medial condyle is directed outward toward the trochlear surface, no such counterpart exists on the outer condyle. When extension is performed with the tibia fixed, the femoral condyles roll and glide on the articular surface of the tibia and the superior surfaces of the menisci until the total area of the external femoral condyle and the corresponding surface of the internal condyle are expended With continued muscular action, the remaining movement to complete extension occurs on the curved oblique portion of the inner condyle This is achieved by internal rotation of the femur until all of the remaining articular surface is consummated in the movement The final position places the knee joint in full extension, and the act achieving it is designated the "screw home" movement The knee joint is now locked in extension If axial rotation is desired it can be accomplished only by unscrewing the

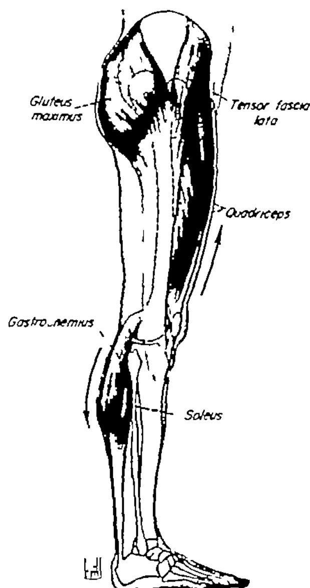


Fig 56 Extensors of knee joint.

knee, which occurs in the first 20 of motion, beyond this point free inward and outward rotation can be performed With attainment of the locked position (full extension) the anterior cruciate ligaments and the articular margin in front of the tibial intercondyloid eminence fit in the anterior region of the intercondyloid fossa of the femur and the greater portion of the curved surface of the anterior aspect of the inner condyle abuts against the semilunar extension of the infrapatellar fat pad and not against the internal meniscus On the lateral aspect of the joint the anterior segment of the lateral meniscus is received in the lateral aspect of the groove on the lateral femoral condyle, while the medial portion of the groove abuts against the articular area in front of the lateral process of the tibial intercondyloid eminence

In the sagittal plane the normal flexion extension range is from approximately 40 flexion to 5 to 10 of hyperextension Axial rotation (inward and outward rotation) varies greatly in different individuals In some, 30 may be demonstrable when the knee is flexed 90 with greater flexion as much as 40 to 50° of axial rotation may be achieved Inward rotation is always greater than outward rotation In complete extension no rotation is possible As pointed out by Steindler, man s faculty to rotate the leg inwardly makes the human gait possible it permits the leg to place the ankle joint the axis of which is in an oblique plane, in the frontal plane thus bringing the foot straight forward

In addition to flexion, extension and axial rotation, other types of motion are demonstrable in the knee joint. These play no part in the functional mechanics of the joint and generally are only minimal in amount.

Sagittal displacement of the tibia on the fixed femur is discernible in both the anterior and the posterior directions when the knee is in the flexed position Under normal condition the extent of the excursion of the femur does not exceed 3 mm

Lateral (abduction-adduction) motion at the knee joint occurs to a limited extent with the knee in the extended position this never exceeds 6 In the hyperextended position, no lateral motion is present while in the flexed position it may exceed 6° but never 12°

Lateral gliding (mediolateral displacement in the frontal plane) is not demonstrable in the normal knee between 90 of flexion and the completely extended position however beyond 90° of flexion minimal amounts of lateral gliding may be elicited

MOVEMENTS OF THE PATELLA

The extensor apparatus pulls the patella upward with great force, in so doing, all structures on the anterior aspect of the joint are made taut thus stabilizing the knee in extension The infrapatellar fat pad and the alar ligaments which adhere to the patella are displaced upward by the pull of the quadriceps muscles, thus preventing impingement of these structures between the condyles of the femur Close inspection of the articular surface of the patella reveals that three paired horizontal facets and a medial perpendicular facet are demonstrable The medial perpendicular facet is a projection backward of the medial portion of the articular surface of the patella it articulates with the semilunar surface on the lateral aspect of the medial femoral condyle when the knee is in extreme flexion As the leg passes from a position of flexion to one of extension, first the superior, then the middle and finally the inferior pair of facets articulate with the patellar surface of the femur With the knee fully extended and the extensor apparatus in a relaxed state, the patella occupies a position on the front of the distal end of the femur and can be moved freely in all directions

DYNAMICS OF THE MUSCLES MOTORIZING THE KNEE JOINT

Extensors of the Knee

The quadriceps is the principal extensor of the knee (Fig 56) Of lesser importance is the tensor fascia lata In cases of complete paralysis of the quadriceps, almost complete extension of the knee may be attained and held by muscles acting indirectly on the knee With the foot in a fixed position the gluteus maximus above and the gastrocnemius below pull the femur backward while the soleus also pulls backward on the proximal end of the tibia, thus extending the knee Both the tensor fascia lata and the gluteus maximus insert into the iliotibial band the greater portion of which passes anterior to the center of the knee joint. It becomes obvious that both these muscles play an important part in

Table 1 Working Ability of the Flexors and the Extensors of the Knee*

Name of Muscle	Shortening in Meters	Cross Section Area in Sq Cm	Work in Kgm = Shortening in Meters × Cross Section Area in Sq Cm × 10
	A. Extensors		
Vasti	0.080	148.30	= 118 640
Rectus femoris	0.081	28 89	= 23 400
Tensor fasc. lat	0 010	7 56	= 0 756
			142 796
	B Flexors		
Semimembranosus	0 064	26.38	= 16 833
Semitendinosus	0 134	7 27	= 9 733
Biceps femoris	0 059	17.37	= 10 248
Gracilis	0 075	4 11	= 3 082
Sartorius	0 070	3 17	= 2.319
			42 215

* Fick. The kilogrammetric values are based on Fick s constant of 10 kg per sq cm to get Recklinghausen s value (3 6) multiply values of last column by 0.36

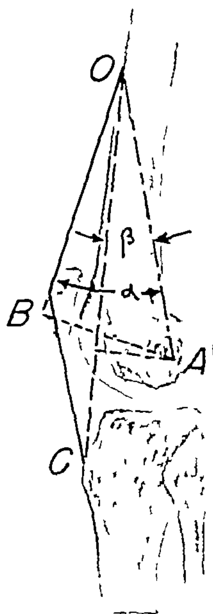


FIG. 57 Anatomic arrangement of the patella in relation to the anterior surface of the femur and the tibia this arrangement deflects the line of pull of the quadriceps anterior to the center of the joint thereby increasing the strength of the muscle by improving the leverage (Redrawn from Steindler Mechanics of Normal Locomotion in Man)

holding the extended position at the knee once it has been attained The quadriceps is the most powerful group in the thigh being the antagonist of 6 flexors of the knee the working ability of this group and of the flexor muscles was calculated by Fick (Table 1) The strength of the quadriceps is three times that of the combined *flexor muscles It is a common* clinical observation that the stability of the knee depends in a large measure on muscle tone particularly of the quadriceps This is best demonstrated in patients with torn collateral or cruciate ligaments Stability of the knee in these patients can be regained by progressive quadriceps exercises designed to restore muscle tone and strength to the optimum point of development

From an anatomic viewpoint the quadriceps comprises the rectus femoris and the three vasti muscles all being ennervated by the femoral nerve Functionally the components of the muscle mass differ The rectus femoris alone cannot extend the leg fully this function is performed by the vasti of which *the medialis is the most powerful* The 3 vasti are designed physiologically to function as a single unit their combined contraction results in pulling the patella upward If the muscles are stimulated *separately by an electric current one observes* that the vastus intermedius pulls the patella directly upward the medialis pulls the patella upward and medially and the lateralis pulls it obliquely upward and laterally *each produces extension of the leg on* the thigh. Stimulation of the rectus femoris draws the patella directly upward Duchenne regards the medialis and the lateralis as antagonists in lateral motion of the patella *and synergists in extension of the knee*

The anatomic position that the patella occupies in relation to the knee joint adds considerably to the mechanical efficiency of the quadriceps This fact is being disregarded by *many surgeons as is evidenced* by the number of patellectomies that are being performed for varied reasons Many observers justify their actions by the belief that the patella is a sesamoid bone and has *no significant role in the movements of the* knee The chief role of the patella is to increase the strength of the quadriceps muscle

by improving leverage This is accomplished by deflecting the line of pull of the motor force necessary to extend the joint anterior to the center of the joint, so that it acts at an angle instead of in a straight line to the bony elements of the articulation (Fig 57) ✓It must be remembered that the axes of muscles are almost parallel with the axis of the elements of the skeleton which are to be put in motion. This arrangement provides for great stability of the parts of the skeleton and for maintenance of equilibrium However, this is only the static function of muscles, the dynamic function is production of rotary movements It becomes apparent that muscle force comprises a rotary and a tangential or axial component. In order to move parts of the skeleton nature must design ways whereby the muscle axes are deflected from the center of rotation thus increasing the angle of application This has been achieved by many ingenious arrangements of the elements involved in producing motion The anatomic arrangement of the patella and the quadriceps is only one of many designs, another will be pointed out in the flexor surface of the knee joint According to Steindler, so long as the angle of deflection of the muscle axes does not exceed 30° the stabilizing component of the muscle force is greater than the rotary element. Such is the arrangement in man, except for isolated instances such as the transverse muscles like the pectoralis and the latissimus dorsi in which the rotary component is greater since their axes of application approach a right angle

Analysis of the role that the quadriceps assumes in the stability and the movements of the knee joint brings forcefully to light the importance of this muscle mass in the maintenance of the erect posture in man This is achieved by the ability to produce powerful extension of the knee to stabilize the knee and to maintain equilibrium In addition to opposing the action of the flexor muscles the quadriceps must also counter balance gravity and body weight These functional demands made on the extensors explain their great muscle volume and great force of action Under normal conditions this muscle has considerable reserve force which is readily demonstrated when one stands on one extremity, the muscle will shorten and becomes tense Transverse fractures of the patella resulting from sudden powerful contraction of the quadriceps with the knee semiflexed are encountered frequently and provide another example of its great strength

The erect posture in man has been achieved by the assumption of new functions by muscles primarily designed to motorize the knee in the pronograde position Gradual stages of development of this new function can be demonstrated in the lower animals MacKenzie points out that in spite of the similar anatomic position of the quadriceps in the platypus and man their functions vary greatly In the former the quadriceps extends the flexed knee, a function that is different from that of supporting the orthograde posture In the ape, quadriceps function is more complex than in the platypus, and in man more complex than in the ape The higher primates in assuming the upright position hold the knees slightly flexed and insist upon using one or both forelimbs for balance The ability of the quadriceps to extend the knee fully and to stabilize the joint in varying positions of flexion to complete extension has been an important factor in the great evolutionary strides of man. It has enabled him to free the forelimbs for prehensile use and to elevate them above his head when in the erect position also, it has permitted him to stand and develop a free bipedal gait. It becomes apparent that the new functions of the quadriceps are late acquisitions in man's evolution This is substantiated by the clinical observation that the intrinsic quadriceps mechanism being very unstable is readily unbalanced by even trivial injuries which interfere with normal joint function This disorder is manifested in the loss of

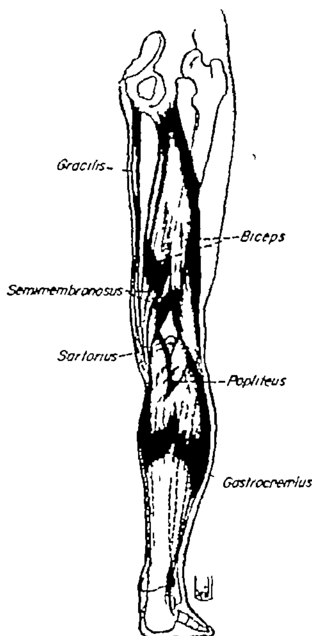


FIG 58 Flexors of knee joint.

muscle volume diminished power of con traction and disorientation of the muscle mass Varying degrees of severity are en countered the more severe derangements present features not unlike flaccid paralysis

According to MacKenzie the functional stages in the evolution of the quadriceps are frequently demonstrable in patients af flicted with poliomyelitis and having quad riceps "paralysis" He noted that in some such instances the patient was unable to stand or when lying in bed unable to raise the heel with the knee extended However the same patient while lying on the unaf fected side was able to extend with ease the affected knee from an acutely flexed posi tion This act is in accord with the common concept of extension of the knee as de scribed in textbooks It becomes apparent that in the above cases the quadriceps may lose the function of recent biologic origin and reverts to the functional status pos sessed by lower animals performing planti grade motion In view of these facts Mac Kenzie said that the "term paralysis of muscles really refers to the loss of some not necessarily all of the functions' He further recorded that recovery of function like loss follows in an ancestral or evolu tionary sequence The observations noted above are applicable also to the deltoid

VASTUS MEDIALIS

This muscle is the most important com ponent of the extensor apparatus Although it works in unison with the other extensors in addition it possesses specialized func tions not observed in the others It is greater in volume and stronger than any one of the other components of the quadriceps Ana tomically its muscle fibers produce the full ness on the lower and inner aspect of the thigh many of the fibers insert directly into the inner border of the patella Func tionally it is responsible for the last 10° to 15° of extension Although it assists exten sion movements through the entire range its most powerful action comes into play in the last few degrees of extension and is thus responsible in a large measure for the locked position of the knee joint or the "screw home" motion

Clinical experience supports the observa tions recorded above Extensive and rapid loss of volume of the vastus medialis always *is associated with loss of full extension of* the knee following traumatic disorders of sufficient severity to interfere with normal joint activity Complete restoration of func

tion of the quadriceps is not achieved in these cases until the vastus medialis has returned to normalcy This is observed frequently in patients following surgical procedures on the knee joint. They complain of "giving way" of the knee joint, particularly on descending stairs, when the full weight of the body is placed on the affected limb This act requires the quadriceps, particularly the vastus medialis, to expend great strength in order to stabilize the knee joint and to maintain equilibrium. If the medialis shows evidence of wasting which is indicative of lessened power, the knee may 'buckle' or "give away" Permanent loss of full extension regardless of the causative agent, always is associated with advanced atrophy of the vastus medialis

Smillie recorded that in instances of destruction of the vastus medialis alone, such as may be seen in war injuries, a full range of motion is possible but the knees constantly "give away" There is no dispute that the above observation is applicable to most cases, however, there are rare exceptions In instances with complete loss of the medialis it is possible for the remaining components of the quadriceps to compensate in power and efficiency to such a degree that the "giving-away" phenomenon does not occur A case in point is that of H C aged 24 who had osteomyelitis of the right femur during childhood Numerous surgical procedures and the presence of an open wound for many months resulted in total destruction of the vastus medialis When examined by the author the patient had no symptoms referable to the affected limb Healing had occurred at the age of 12 there had been no recurrence of the infection during the following 12 years While attending college the patient participated in strenuous sports such as football and basketball at no time did he note any instability in the knee joint Examination of the limb revealed complete absence of the medialis but marked hypertrophy of the remaining components of the quadriceps

Flexors of the Knee

The principal flexors of the knee are the semitendinosus, the semimembranosus the biceps femoris the gracilis and the sartorius Some muscles in the calf of the leg which expand the knee joint also produce flexion These are the popliteus, the plantaris and the gastrocnemius The flexion action of this latter group does not come into play until the knee has been flexed slightly by the flexors in the thigh. The outer flexors are capable of greater leverage because their point of application is deflected a greater distance than that of the inner from the axis of the skeletal com-

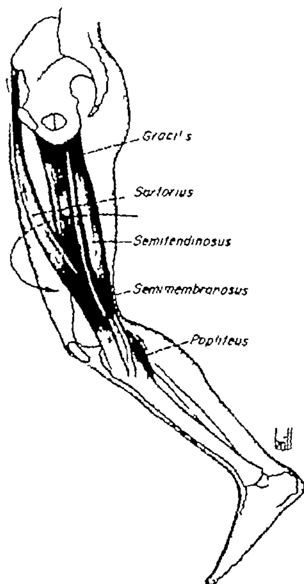


Fig 59 Internal rotators of knee.

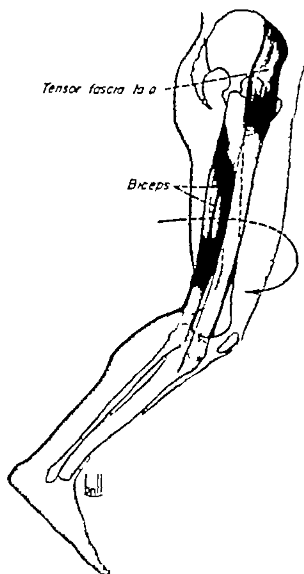


Fig 60 External rotators of knee

ponents of the joint The flexor tendons are deflected in their path as they course over posterior portions of the femoral condyles which project considerably backward (Fig 58)

Rotators of the Knee

The same muscles producing flexion of the knee are the rotators Internal rotation is affected by the semimembranosus the semitendinosus the sartorius and the gracilis all passing around the medial aspect of the knee joint to insert into the tibia. In addition the popliteus is also a powerful internal rotator (Fig 59) The principal external rotator is the biceps femoris, which passes distally on the lateral side of the knee to reach the head of the fibula When the knee is slightly flexed the tensor fascia lata aids in flexion movements by its pull on the iliotibial band (Fig 60)

It was recorded previously that in the fully extended position little or no rotary motion is possible at the knee joint In the locked position the configuration of the medial femoral condyle causes the femur to rotate inward (when the leg is fixed) The internal rotators play an important role in unwinding the knee in order to initiate flexion When the leg is fixed by taking their fixed point from below they rotate the femur on the leg outward With completion of this act flexion at the knee is possible The popliteus muscle assumes a very significant part in the execution of this movement.

MAINTENANCE OF STABILITY AT THE KNEE JOINT

Under normal conditions the muscles of the thigh particularly the quadriceps and some muscles in the posterior aspect of the leg the gastrocnemius and the popliteus are the principal stabilizers of the knee in the extended position As will be shown subsequently this is especially true in patients with torn collateral or cruciate ligaments or both In the treatment of these lesions it becomes apparent that the goal is good tone and strength in the quadriceps all therapeutic measures should be directed toward this end In addition it has been shown that the configuration of the bony components of the knee are such that stability is enhanced when extension is completed The "screw home" phenomenon made possible by the prolongation of the anterior portion of the articular surface of the medial condyle is the most important factor in this movement Normal erect body position is another factor once extension of the

knees has been achieved, the center of weight distribution falls slightly anterior to the center of movements in the knee joints, thus tending to maintain the knees in the extended position It will be shown further that in extension considerable tightening of the collateral ligaments occurs, a factor adding to the stability of the joint. In varying degrees of flexion of the knee, the gluteus maximus and the muscles of the posterior aspect of the leg mentioned previously play an important role in maintaining stability and equilibrium, thus being of considerable assistance to the quadriceps Finally, the iliotibial band, because of its anatomic position, must be considered as a stabilizer of both the hip and the knee It runs from the ilium to the tibia crossing both the hip and the knee The gluteus maximus inserts into its posterior portion, and the tensor fascia latae into the anterior Contraction of these muscles aids in stabilizing through the iliotibial band, flexion extension movements at the hip Inasmuch as the iliotibial band passes anterior to the center of movements of the knee, it contributes to the stability of this joint when extended

FUNCTIONAL MECHANISM OF MENISCI, CRUCIATE AND COLLATERAL LIGAMENTS

Much has been written on the movements of the knee joint and the functional mechanism of the menisci the cruciate and the collateral ligaments. A survey of this literature reveals considerable disagreement among the many workers interested in this subject In fact, many assertions are ambiguous and contradictory leaving the reader in a state of confusion In recent years the work of Brantigan and Voshell on the mechanics of the ligaments and the menisci of the knee joint has thrown some light on this obscure problem. In 1911, Fick published his observations and conclusions made in a meticulous and comprehensive investigation on the anatomy and the mechanics of the knee joint Although the aforementioned two studies contained many observations and conclusions which were in agreement with one another, they were in total discord with those recorded by many other observers. The knee joint with its menisci and ligaments is vulnerable and subjected frequently to abnormal stresses, producing minor or severe injuries to one or several of the components of this articulation It becomes obvious that knowledge of the mechanics of the various structures and the significance of their individual role in the stability and the over-all performance of the movements of the knee joint is essential This information is the basis for the wisdom of accepting some injuries and refusing to accept others In the latter instance an attempt is made to restore the disrupted structures to anatomic normalcy by surgical intervention Because of the many discrepancies encountered in the literature, an investigation of the subject was made (Table 2) The plan of the study paralleled in many respects (particularly the preparation of the specimens) that made by Brantigan and Voshell

Materials and Methods Employed in the Study

This investigation was conducted together with a study on degenerative lesions of the knee joint, the latter investigation will be reported in a subsequent publication For both problems, 86 fresh knee joints obtained from high amputations were dissected and studied Only knee joints of patients who were unaware of any disability relative to their knees were used in the study of the ligaments, moreover, upon physical examination prior to amputation these knees disclosed no objective evidence of any dysfunction The study on motion and function of the knee joint was carried out on intact fresh joints and on stripped fresh joints. In the former the various measurements were made on joints with all

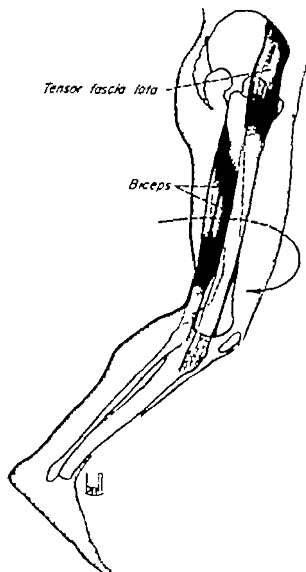


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TABLE 2

	Case No	34	40	41	42	43	44	45	46	50	52	54	61	64	65	66	82	94	Average
		SPECIMENS																	
I	Tibial (medial) coll. ligament																		
	Epicondyle to distal insertion	10	9.8	11 3	8 9	12 4	10 7	9.5	10.5	8.5	11.6	11.5	11.2	11.5	10.3	11 1	9 9	10 1	10 4
	Tibia surface to proximal insertion	2.0	2.3	1 7	2.0	2.5	3 7	6	.3	2.6	1.5	4.2	2 1	2.0	2.6	2.8	1.6	1 4	2.2
	Tibia to beginning of distal insertion	4 1	3 6	6.3	3.8	5.2	5.0	3 4	3.3	3 7	4.5	5.5	5.2	4.5	4 7	4 4	4.5	4.8	4.5
	Tibia surface to end of distal insertion	6.5	5 9	8 7	5.6	7 7	7.0	7.2	6.3	5.5	7.2	8.2	7.0	7.0	6 9	7.8	7.0	6.4	6 6
II	Presence of bursa	+	+	+	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+94% −.06%
	Size of bursa	2 1	1.3	2 6	2 7	1.3	3.0												2 1
III	Post displacement of tibial ligament	.5	4		4	1.2	4		.3			4	1	4		.2	.5	6	4
IV	Fibular (lateral) coll ligament	6.5	5.6	5.5	5.5	6.5	6.0	5.5	5.1	6.0	7 0	6.5	6.8	6.5	6.0	6.5	6.0	6 0	6.08
V	Presence of																		
	Ligament of Wrisberg	+	−	+	+	+	−	−	+	+	+	−	−	−	−	−	−	+	+53% −57%
	Ligament of Humphry	−	+	−	−	−	+	−	−	−	−	−	−	+	−	−	−	−	+20% −80%
	Both ligaments	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−100%
VI	Displacement																		
	Medial cartilage	3	4	.3	.3	7	.3	.3	1	.3	.3	.5	.2	.2	.3	.3	4	.2	.3
	Lateral cartilage	8	7	1.0	9	1 4	9	1.0	.5	1.3	1.0	2.0	6	1 0	.5	.6	6	.6	9
VII	Fusion capsule with post cruciate	−	−	−	+	−	+	−	−	−	−	+	−	−	−	−	−	−	+21% −79%

17 specimen were studied to compile the measurements contained herein. All figures given are in centimeters

the latter the same measurements were recorded on joints stripped of soft tissues except the ligaments and the menisci In order to evaluate the role of the individual ligaments, they were severed singly and in combination When this was done on fresh intact specimens the ligaments were cut through small stab wounds which were closed before the measurements were made It was found necessary to split the joints in several planes so that the function and the significance of certain ligaments could be studied, this is particularly true of the cruciate ligament. All measurements were made with the femur fixed (Fig 61) Lateral motion comprises two elements, abduction and adduction—rocking of the tibia on the fixed femur

Measurement of lateral and rotary motion of the knee joint in different degrees of extension and flexion necessitated the construction of the apparatus shown in Figure 61

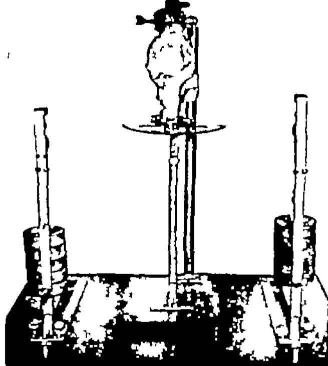


Fig 61 Apparatus employed to study motion of the knee joints in different planes, observe that the femur is fixed

Role of Ligaments and Menisci During Normal Extension and Flexion Movements of Knee Joint

With the knee joint extended completely both tibial and fibular collateral ligaments are taut with hyperextension tension in these structures increases (Fig 62) This same phenomenon is demonstrable in the cruciate ligaments the tendon of the popliteus muscle and the fibrous cords running from the periphery of the posterior segment of the external meniscus to the inner and posterior aspect of the medial condyle of the femur (ligament of Wrisberg, ligament of Humphry or both) In the extended position in nonweight bearing joints the menisci fit snugly in their grooves in the corresponding condyles of the femur but they are not compressed compression of these structures between the femoral and the tibial condyles does not occur even when hyperextension is executed Instead the lateral extensions of the infrapatellar fat

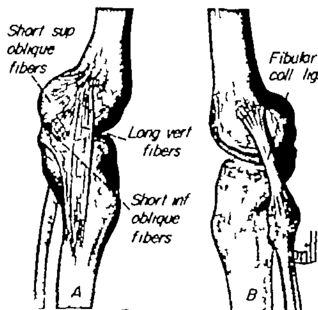


Fig 62 With the knee hyperextended, the tension in the tibial and the fibular collateral ligaments increases (A) Tibial collateral ligament (B) Fibular collateral ligament.

pad are compressed by extension and hyper extension of the joint This is evident particularly at the end of extension when the 'screw home' movement is being completed

When flexion is *initiated with the tibia* fixed, unscrewing of the joint is discernible this is achieved by external rotation of the femur on the fixed tibia During the first few degrees of motion, unwinding of the joint is barely perceptible and becomes more apparent with each successive degree of flexion reaching its maximum after 20° of flexion have been performed As previously recorded, the rotary movements responsible for screwing and unscrewing of the knee joint are around an axis which passes near the *medial condyle of the femur*

Both menisci migrate forward on extension and backward on flexion of the knee joint the motion takes place between the menisci and the corresponding articular surfaces *of the plateaus of the tibia (Fig 63 A* and B) At the beginning of flexion there is immediate backward displacement of the external meniscus The greatest amount of the excursion occurs after 5° to 7° of flexion a *phase in flexion* which corresponds to the end of the unscrewing maneuver of the knee joint The amount of backward displacement varies from 5 mm to 1 4 cm., the average in this series being 9 mm During the first phase of flexion the internal meniscus remains stationary backward displacement *begins after 17° to 20°* of flexion have been achieved The amount of displacement varies from 1 mm to 7 mm the average being 3 mm this is considerably less than that recorded for the opposite *meniscus (Table 2) No further* displacement of the internal structures occurs after 70 of flexion beyond this arc the meniscus is gripped firmly between the posterior flare of the articular surface of the medial condyle of the femur and the articular surface of the tibia This situation differs from that noted on the outer side of the joint It can be demonstrated readily that backward *displacement of the external* fibrocartilage continues until 110° of flexion has been consummated beyond this arc, in forced hyperflexion the posterior segment of the meniscus tends to slide posteriorly over the *posterior flare of the external* condyle of the femur thereby preventing compression between the condyle of the femur and that of the tibia. In flexion posterior displacement of the external structure is enhanced by the *ligaments of Wrisberg* and Humphry these structures also prevent anterior displacement of the meniscus during abnormal maneuvers which would tend to trap the structure between the condyles of the femur and the tibia. It becomes apparent that they play a significant role in making the *posterior horn of the external meniscus* less vulnerable to injury A comparable situation does not exist on the posterior aspect of the inner side of the knee joint.

It was noted previously that the configu*ration of the condyles of the femur* plays a very significant role in controlling rotary movements with the knee in extension. With beginning of flexion unlocking of the knee commences after this phase is executed *tension of the ligamentous apparatus* is diminished because the posterior halves of the condyles of the femur are segments of smaller circles than the anterior halves Inasmuch as the axis of rotation is nearer the *medial condyle of the femur* it becomes obvious that the lateral condyle must describe a greater arc during rotatory movements than the medial and hence must be freer The greater range of excursion of the external meniscus as compared with that of the internal supports this observation

Tibial Collateral Ligament

This ligament is the most important component of the *ligamentous apparatus* and its frequency of injury is greater than that of any of the other ligaments of the knee joint Its structure plays a pertinent role in the stability of the joint both in extension and flexion It consists *of a deep and a*

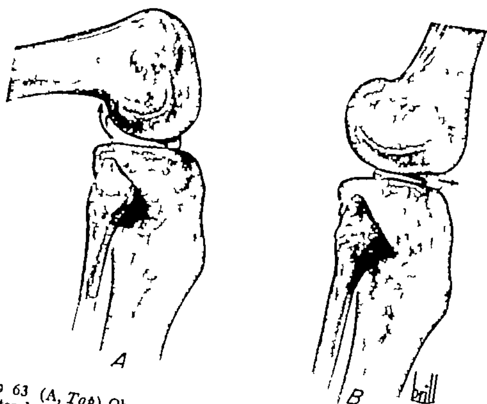
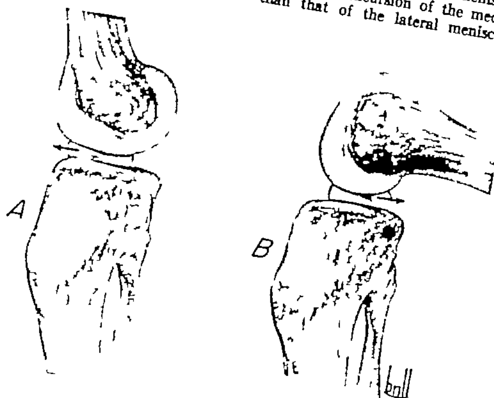


FIG 63 (A, *Top*) Observe the forward and backward excursion of the lateral meniscus with extension and flexion of the knee joint. Also note that at the extremes of flexion the posterior segment of the meniscus tends to slide posteriorly and upward over the posterior flare of the external femoral condyle, hence compression of the meniscus is prevented (B *Bottom*) The backward excursion of the meniscus meniscus is considerably less than that of the lateral meniscus



superficial layer The deep layer is smaller and consists of short vertical fibers extending from the medial epicondyle to the articular margin of the tibial condyle and continuing distally for a short distance on the medial aspect of the condyle It blends with the fibrous capsule and is firmly adherent to the internal meniscus. The superficial portion is triangular in shape with its base located anteriorly and its apex posteriorly it is subdivided further into anterior and posterior portions The anterior fibers are inserted proximally into the medial femoral epicondyle the line of attachment to the bone is at a slight angle Distally the fibers are attached to the medial aspect of the tibia at a distance of 0.3 cm to 4.2 cm (the average being 2.2 cm) below the articular margin of the tibial plateau the fibers then continue downward for a distance of approximately 2 1 cm (Fig 64) The posterior portion comprises the superior oblique and the inferior oblique fibers They lie above and below the joint line respectively and are directed obliquely toward the inner and posterior aspect of the tibial condyle they blend and insert into the condyle immediately superior and lateral to the site of the insertion of the tendon of the semimembranosus In fact the inferior fibers arch over the tendon of the semimembranosus to reach their point of bony attachment At the level of the joint line the converging oblique fibers blend with the periphery of the internal meniscus forming a fixed point posterior to the middle of the tibial ligament

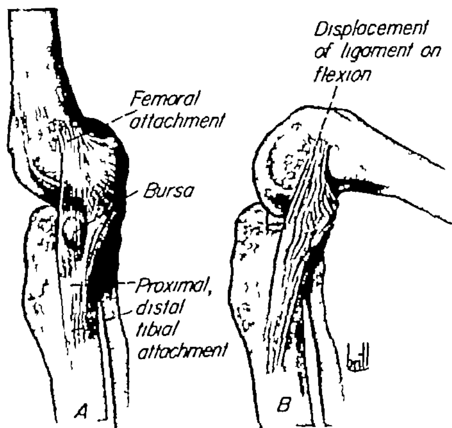


FIG. 64 Tibial collateral ligament (A) Note that its posterior oblique fibers blend with the periphery of the meniscus at the level of the joint posterior to the middle of the ligament Frequently a bursa is encountered between the meniscus and the anterior portion of the superficial layer of the ligament. (B) In flexion the posterior fibers relax however even in complete flexion some of the anterior vertical fibers are *still taut* Also in flexion the ligament as a whole shifts backward.

The anterior portion of the superficial layer is attached loosely to the underlying meniscus Frequently, a bursa is interposed between the two structures, in this study a bursa was present in 94 per cent of the specimens Abbott et al observed that the posterior oblique fibers blend with the joint capsule, forming a hemispherical pouch which is lax in flexion and tense in extension, the pouch contains the posterior part of the medial femoral condyle In extension the posterior one half of the medial femoral condyle is grasped firmly by the inner surface of the pouch, this arrangement enhances considerably the stability of the knee in extension. According to the above workers if this arrangement is destroyed it results in instability of the knee in the locked or extended position

In extension all portions of the tibial collateral ligament are tense, allowing no abduction rocking or axial rotation of the tibia (Fig 64) As flexion begins the posterior oblique fibers relax beginning from posterior to anterior, more and more fibers relax as flexion increases However, even in extreme flexion the long anterior superficial fibers are still taut, preventing any abduction rocking, and some axial rotation is still permitted It becomes apparent that throughout the entire arc of flexion some portion of the ligament is taut During flexion the entire ligament shifts slightly backward in relation to the medial tibial condyle, the amount of displacement varies from 1 mm. to 1.2 cm, the average being 4 mm This distance was measured by noting the extent of displacement backward of the anterior margin of the long anterior fibers of the ligament When the knee is flexed 90° the amount of abduction at the joint line ranged from 3 mm. to 8 mm. the average being 5 6 mm

Fibular Collateral Ligament

This structure comprises a deep and a superficial portion (Fig 65) The small deep component extends from the lateral epicon

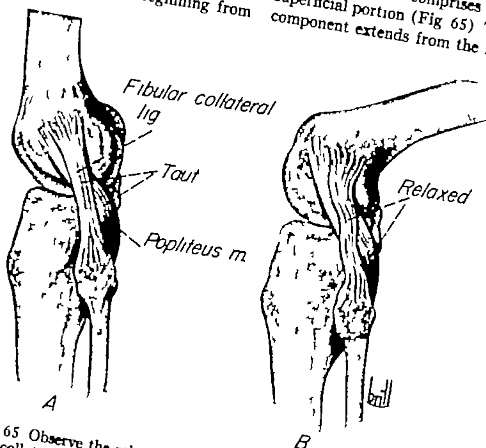


Fig 65 Observe the relation of the tendon of the popliteus to the fibular collateral ligament (A) both structures are taut in extension and (B) relaxed in all positions of flexion

dyle of the femur to the medial aspect of the upper surface of the fibula and to the styloid process Between the ligament and the external meniscus is interposed the tendon of the popliteus muscle and its synovial sheath Its posterior margin blends with the fascial covering of the popliteus muscle and contributes to the formation of the arcuate ligament.

The superficial portion or the long external ligament is a stout fibrous cord stretching from the lateral epicondyle of the femur to the upper surfaces of the head of the fibula lateral to the deep portion. The tendon of the biceps femoris separates the two layers of the fibular collateral ligament, but the superficial ligament divides the tendon into a superficial and a deep lamina

In extension and hyperextension this ligament is taut and precludes any adduction rocking of the tibia However it is relaxed in all positions of flexion, the same is true of the tendon of the popliteus muscle (Fig 66) In the flexed positions the ligament functions as a checkrein to axial rotation in both medial and lateral directions it acts essentially on the lateral condyle of the femur

Cruciate Ligaments

Although these structures are less developed in the knee joint of man as compared with the cruciate ligaments found in lower primates, nevertheless they play a significant role in the functional mechanics of the knee joint. The intricate manner in which they function is primarily the result of the peculiar arrangement of their insertions into the femoral condyles In general the insertion of one is the mirror image of the other The posterior cruciate ligament is the larger of the two ligaments and its femoral in

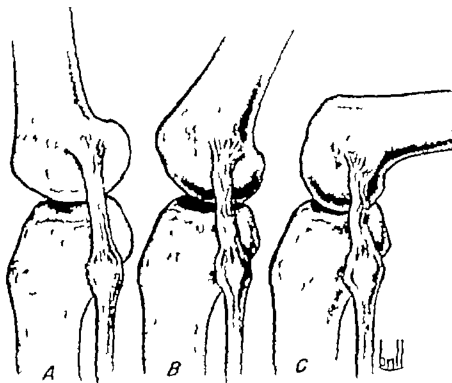


Fig 66 The fibular collateral ligament The ligament is taut in (A) hyperextension and (B) extension but (C) relaxed in all positions of flexion

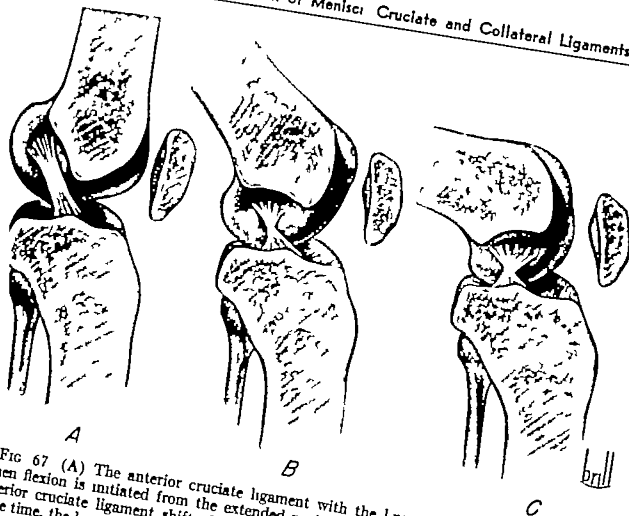


FIG 67 (A) The anterior cruciate ligament with the knee extended. (B and C) When flexion is initiated from the extended position the femoral attachment of the anterior cruciate ligament shifts from a vertical to a horizontal plane (C) at the same time, the ligament twists on its longitudinal axis counterclockwise. The reverse is true when the knee is extended from the fixed position.

sertion is slightly higher and also more anterior than that of the anterior cruciate ligament

ANTERIOR CRUCIATE LIGAMENT

In this study with the knee flexed 90° the average length of this structure is 2 7 cm. Its tibial attachment is located in the nonarticular area of the upper end of the tibia immediately in front of the intercondyloid eminence It passes obliquely upward backward and laterally and inserts into a small depressed area on the posterior aspect of the inner surface of the lateral condyle of the femur Just before the ligament reaches the femoral condyle its fibers spread out so that the area of bony insertion is greater than the diameter of the ligament at its middle The direction of the plane of insertion of the fibers into the femur changes with flexion and extension (Fig 67) In the position of full extension the line of insertion approaches the vertical plane, the anterior fibers of the ligament are located at the upper level of the line of attachment while the posterior fibers are situated at the lower level In this position the posterior fibers are less taut than the anterior, but in hyperextension they become tense When flexion is initiated the plane of the femoral attachment begins to shift from a vertical to a horizontal position at the same time the posterior fibers shift forward and the anterior fibers shift backward It readily becomes obvious that the ligament as a whole twists counterclockwise on its longitudinal axis on flexion and unwinds in extension this twisting and untwisting of the fibers is the result of the changes in the axis of the femoral insertion of the ligament



FIG 68 (A) The posterior cruciate ligament with knee in the extended position (B) as to (C) As flexion increases from the extended position the plane of the line of the femoral insertion changes from a horizontal to a vertical plane at the same time the ligament twists on its longitudinal axis in clockwise fashion. During extension the ligament unwinds the direction of the twist is opposite to that of the anterior cruciate ligament (Fig. 67)

The ligament is tense only in hyperextension and in complete flexion In all other phases of flexion some portion of the ligament is less taut than others but none of the fibers is tense This difference in degree of tautness while the knee is in varying degrees of flexion with the tibia fixed permits a certain amount of axial rotation of the femur on the tibia and some adduction rocking also the femur can be displaced backward a few millimeters in the sagittal plane It becomes apparent that when the tibia is fixed and the knee is approaching complete extension the anterior cruciate ligament functions as a guide wire at the end of which the lateral femoral condyle performs when the femur is fixed it controls lateral rotation of the tibia This is the most important function of the anterior cruciate ligament Derangement of the normal lateral rotation of the tibia (or medial rotation of the femur) is responsible for a large percentage of the lesions of the anterior cruciate ligament The control of the anterior cruciate and the fibular collateral ligaments on the lateral condyle is responsible for the final compulsory rotation" described by Fick As the knee moves from a position of flexion to one of extension the forward motion of the lateral condyle is checked at approximately 160 by the tightening of the two aforementioned ligaments With continued muscular action complete extension can be achieved only by backward gliding of the medial condyle and internal rotation of the femur when complete extension is attained both the cruciates and the collateral ligaments are tense holding the joint in the locked position

As previously recorded the anterior cru

ciate ligament is a strong checkrein to posterior displacement of the femur in the sagittal plane. However, a minimal amount of displacement is usually discernible in most points when in varying degrees of flexion.

POSTERIOR CRUCIATE LIGAMENT

With the knee extended the posterior cruciate ligament measures 3.3 cm in length It is attached to the posterior intercondyloid fossa of the tibia just behind the posterior horn of the internal meniscus Its fibers pass obliquely upward, forward and medially crossing the anterior cruciate ligament, and gain attachment in a depressed area on the lateral aspect of the medial condyle of the femur (Fig 68) The relation of the line of insertion of the femoral attachment to the articular surface of the tibia varies with the position of the knee joint In the position of complete extension, the line of insertion is almost in a horizontal plane the posterior fibers are more taut than the anterior fibers. In the hyperextended position the posterior fibers become tense, while the anterior ones relax this is effected by a shift in the plane of the femoral insertion of the ligament which now is directed downward and forward, placing the insertion of the posterior fibers at a higher level than that of the anterior fibers When flexion is initiated the plane of the line of insertion begins to reverse itself so that at 90° of flexion it lies in a vertical plane In approaching this position the posterior fibers relax and shift forward and beneath the anterior fibers, which now become taut as flexion continues the posterior fibers shift anteriorly still further while the anterior fibers are displaced posteriorly It is apparent that during flexion the fibers of the posterior cruciate ligament twist on their longitudinal axes in clockwise fashion and unwind during extension The direction of the twist is opposite to that of the anterior cruciate ligament Throughout flexion some portion of the ligament is taut thereby controlling the movements of the medial femoral condyle at all times throughout flexion

This tenseness checks the range of internal rotation of the femur and abduction rocking in positions of flexion it precludes any forward displacement of the femur on the tibia

ANALYSIS OF CONTROL OF DIFFERENT LIGAMENTS ON MOTIONS OF KNEE JOINT

Sagittal Motion

In complete extension the collateral and the cruciate ligaments are taut, also, the posterior capsule with its reinforcing ligaments—the arcuate ligament on the outer aspect and the oblique popliteal ligament (a prolongation of the semitendinosus tendon) on the inner aspect—is also tight When the joint is hyperextended, the aforementioned structures become tense, precluding any further motion in this direction Division of the posterior capsule transversely permits the joint to go into more degrees of hyperextension (5°), if the posterior cruciate ligament is also severed 5° to 8° more hyperextension may be achieved Beyond this point the bony configuration of the femoral condyles, and in a measure the anterior cruciate ligament and the tendon of the popliteus, prevents further hyperextension It was pointed out by Brantigan and Voshell and confirmed by this investigation that when the patellar surfaces of the femoral condyles are removed and all ligaments are left intact in stripped fresh joints, as much as 100° of hyperextension may be achieved, yet the tension in the ligaments is not altered materially The articular surfaces of the femoral condyles that articulate with the patella are segments of circles larger than those which articulate with the tibia Hence when the knee is completely extended and hyperextended the larger patellar portions of the femoral condyles tend to distract the smaller portions away from the tibial plateaus In

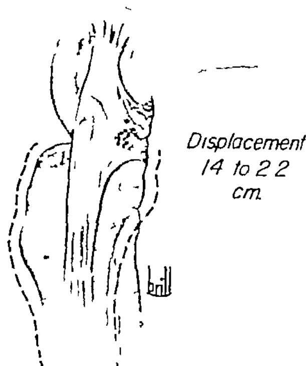


FIG 69 In fresh stripped joints when both cruciate ligaments are cut and the knees are flexed to a right angle, antero-posterior displacement of the tibia increases to as much as 1 4 cm to 2.2 cm. In part, this is due to relaxation of the fibular collateral ligament and the posterior oblique fibers of the tibial collateral ligament when the knee is in a position of flexion.

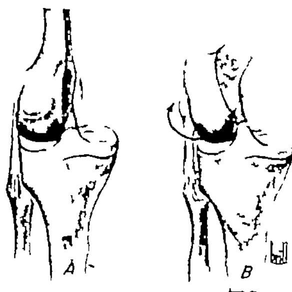


FIG 70 When the anterior cruciate ligament is cut, the lateral femoral condyle tends to slide off the tibial plateau during the act of flexion. (In this figure the medial femoral condyle and the posterior cruciate ligament have been omitted purposely in order to depict more clearly the relation of the lateral condyle to the tibial plateau.) (A) Denotes the normal relationship of the lateral femoral condyle to the tibial plateau when the knee is in the extended position (B) depicts the femoral condyle sliding off the tibial plateau when the knee is flexed.

so doing there is a tendency to increase the interval between the attachments of all the femorotibial ligaments thereby increasing the tension in these structures In hyperextension the anterior portions of the femoral condyles make firm compression on the medial and the lateral projections of the infrapatellar fat pad which now function as cushions between the femoral and the tibial articular surfaces

Upon flexion of the joint the posterior portion of the tibial collateral and the entire fibular collateral ligament relax as flexion increases more fibers of the tibial collateral relax while the ligament as a whole gradually shifts backward In complete flexion the long anterior fibers of the tibial ligament are tense the fibular collateral ligament is relaxed and the cruciate ligaments are also tense In intact joints further flexion is prevented by the menisci interposed between the femur and the tibia the femoral portion of the posterior capsule and the heads of origin of the gastrocnemius muscle which are wedged between the posterior surfaces of the femur and the tibia

In summation the structures which restrain hyperextension are both collateral and both cruciate ligaments the posterior capsule the tendon of the popliteus the oblique and the arcuate ligaments the medial and the lateral prolongations of the infrapatellar fat pad and the patellar portions of the femoral condyles Hyperflexion is inhibited by both cruciate ligaments the posterior portion of the fibrous capsule and

the heads of the gastrocnemius muscle, the posterior segments of the menisci and the configuration of the femoral condyles It is important to reiterate that flexion and extension also are governed by the muscular apparatus which functions in unison with the sensory mechanism of the supporting ligaments and the capsule of the knee joint

Anteroposterior Displacement of the Tibia on the Femur

In stripped fresh specimens if the anterior cruciate ligament is divided and all other ligaments are left intact, the amount of anterior displacement of the tibia on the fixed femur varies from 2 mm to 5 mm while the knee is in 180° extension In extension both collateral ligaments are tight and tend to check the amount of anteroposterior motion of the tibia on the femur When both cruciates are cut and the collaterals are intact hyperextension is increased by 22° to 32° in flexion (90°) anteroposterior displacement of the tibia increases to as much as 1 4 cm to 2 2 cm (Fig 69) In flexion the fibular collateral and the posterior fibers of the tibial collateral are relaxed, hence enhancing anteroposterior displacement. In addition with the anterior cruciate cut, when the knee proceeds into full flexion the lateral femoral condyle is no longer held in a fixed position in relation to the tibia but tends to slide off the tibial plateau (Fig 70) This is also demonstrable when both cruciates are cut (If the tibia is fixed one readily notes that medial rotation of the femur is increased)

Division of the anterior cruciate and the tibial collateral ligament result in a definite increase in the amount of anterior displacement of the tibia (anterior drawer sign) In this series with the knee flexed to a right angle it ranged from 1 8 cm to 2 6 cm (Fig 71) It becomes apparent that an intact tibial collateral ligament plays a major role in checking the anteroposterior excursions of the tibia on the femur In extension the entire ligament partakes in this function, in flexion only the long anterior fibers are tight. When all the ligaments are divided, the joint is extremely unstable generally in stripped joints the extent of forward displacement exceeded 2 cm and in several specimens it reached as high as 2 9 cm. It becomes obvious that excessive anteroposterior motion invariably indicates disruption of the anterior cruciate and the tibial collateral ligaments or the tibial collateral and both cruciate ligaments Although an intact capsule and the muscular apparatus tend to reduce the amount of instability recorded above nevertheless even in the living when both the tibial collateral and the anterior cruciate ligaments are implicated the integrity of the joint is so impaired that a strongly positive anterior drawer sign and abnormal abduction rocking of the tibia are readily demonstrable

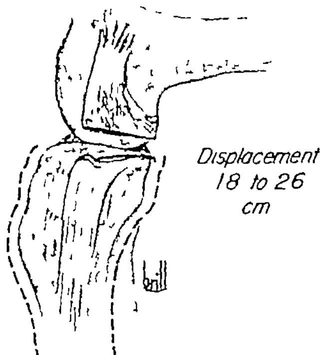


Fig 71 With the knee flexed to a right angle, severance of the anterior cruciate and the tibial collateral ligament permitted anterior displacement of the tibia ranging from 1 8 cm. to 2 6 cm.

This study discloses that the anterior cruciate ligament prevents anterior displacement of the tibia on the femur, and

the posterior cruciate prevents posterior displacement. Also the fibers of these ligaments are so arranged and inserted into the femoral condyles that some portion of the ligaments is always taut during flexion and in full flexion and extension they are tense This feature converts the anterior cruciate into a checkrein which controls the movements of the lateral femoral condyle on the tibia while the posterior cruciate ligament controls the movements of the medial femoral condyle Although all ligaments are important to the stability of the knee joint it appears that the combination comprising the anterior cruciate and the tibial collateral ligament contributes most to the stability of the joint

Lateral Motion (Abduction and Adduction Rocking of the Tibia on the Femur)

In full extension with all ligaments intact a few degrees of rocking of the tibia on the femur is discernible It varies from 0 to 6° at right angle flexion rocking increases slightly varying from 5° to 12° Division of

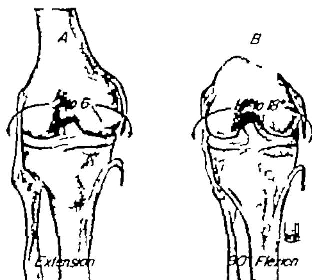
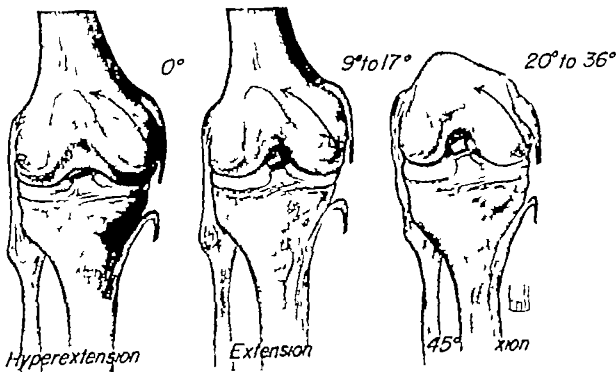


Fig 72 (*Top*) (A) In extension with only the tibial collateral ligament cut 0° to 6 lateral motion is demonstrable (B) with the knee flexed 90 lateral motion is increased from 14 to 18

Fig 73 (*Bottom*) (A *Left*) When the anterior cruciate and the tibial collateral ligaments are divided completely no abnormal lateral motion is discernible in hyperextension (B *Center*) in extension motion ranges from 9 to 17 and (C *Right*) in 45 flexion from 20 to 36



the tibial collateral ligament alone reveals no abnormal lateral motion in full extension, however, in 20° of flexion some abnormal abduction rocking of the tibia on the femur is demonstrable It varies from 8° to 12°, and in 90° flexion 14° to 18° (Fig 72) No abnormal lateral instability is demonstrable when the anterior or the posterior cruciate ligament is cut and the remaining ligaments are left intact. When the anterior cruciate and the tibial collateral are divided completely, no abnormal lateral motion is discernible in hyperextension However, in full extension (180°) from 9° to 17° of outward lateral motion (abduction rocking) is possible in 45° flexion from 20° to 36° of motion may be present (Fig 73)

If both the cruciates are divided and the collateral ligaments remain intact, no abnormal rocking is noted either in hyperextension or extension In flexion the relaxation of the fibular collateral ligament, the posterior fibers of the tibial collateral ligament and the popliteus tendon permit some adduction motion In this study with the knee in 90° flexion it ranged from 12° to 15°, no abnormal abduction motion was demonstrable

In the light of this investigation it becomes apparent that in addition to the stabilizing influence of the muscles the tendons and the aponeurosis about the knee joint the capsule, both cruciate ligaments the tibial and the fibular collateral ligaments are responsible for lateral stability of the joint in extension Also, these structures with the exception of the fibular collateral ligament control lateral motion in flexion. Since the function of the collateral and the cruciate ligaments overlap insofar as lateral stability of the joint is concerned it becomes obvious that abnormal forces sufficient to disrupt one structure are very likely to jeopardize the integrity of others A good example of this is the frequency with which a complete rupture of the tibial collateral ligament is associated with a rupture of the anterior cruciate ligament Knowing the function of these two structures, the mechanics of this combined lesion is readily understandable In the chapter dealing with the normal anatomy of the knee joint, the close relationship of the deep fibers and the posterior oblique fibers of the tibial collateral ligament to the fibrous capsule and the periphery of the medial meniscus was revealed. This intimate anatomy points to the possibility that in combined lesions (ruptures of the tibial collateral and the anterior cruciate ligaments) the fibrous capsule must be torn and that there may be an associated lesion of the medial meniscus Clinical experience has proved that such complex lesions do exist and must be anticipated

Rotary Motion

With all ligaments intact (in intact fresh joints) no rotation is demonstrable in the extended or the hyperextended knee joint Some medial rotation is possible with the onset of flexion, which is greatest at approximately 30° of flexion (24° to 30°) lateral rotation is only 6° to 8° At 90° of flexion and in full flexion there is no appreciable increase over that noted at 30° Medial rotation in the flexed knee joint occurs because the fibular collateral ligament relaxes, lateral rotation is prevented by the configuration of the tibial collateral ligament, particularly its oblique posterior portion which wraps it tightly around the periphery of the femoral condyle when lateral rotation is attempted In a measure the tendon of the popliteus muscle also restricts the arc of both medial and lateral rotation

In the extended position no medial or lateral rotation of the knee joint is discernible when the tibial collateral ligament alone is severed In the flexed position there is a considerable amount of lateral rotation (up to 30°) but medial rotation is *not significantly* increased over the range noted when all ligaments are intact (Fig 74) Severance of fibular collateral ligaments allows no abnormal increase in medial or lateral

rotation in the extended position, but in flexion lateral rotation is increased (Fig 77) Cutting of both cruciate ligaments does not effect any significant increase in the rotation of the joint in the position of extension however, in flexion both medial and *lateral rotation are increased to 45 to 50* (Figs 78 and 79)

When the tibial collateral ligament is cut in combination with the anterior cruciate no abnormal medial rotary motion is apparent with the knee extended but an average range of 18° of lateral rotation is possible With the knee flexed 90° both medial and lateral rotation are increased to approximately 45°

Division of both cruciates and both collateral ligaments renders the joint exceedingly unstable It becomes apparent that *the cruciate the collateral ligaments the* capsule and the tendon of the popliteus muscle play a major role in rotary stability of the knee joint In the flexed position the fibular collateral ligament and the popliteus tendon are relaxed hence they do not contribute to rotary stability In this position the capsule, the cruciate ligaments and the tibial collateral ligament are the prime stabilizing agents however in the position of extension all the aforementioned structures participate in providing rotary stability

Ligaments Perform as a Functional Unit

The integrated action of the individual ligaments together with the muscular apparatus, makes possible the smooth precision movements of the knee joint The closely related action of each ligament is understood readily when the role of each ligament is analyzed during normal flexion and extension of the joint With the tibia fixed and the knee flexed fully the tibia is *rotated medially on the femur The relaxed* fibular collateral ligament the reduction in tautness of the anterior cruciate ligament and the relaxed tendon of the popliteus permit the tibia and the femur to assume the

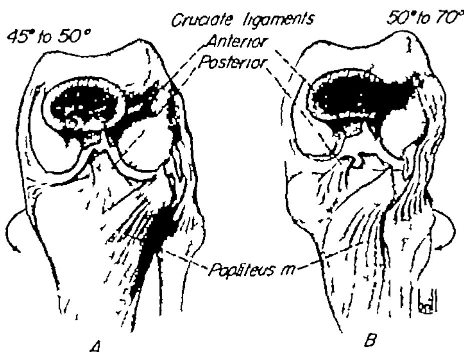


Fig 79 With both cruciate ligaments cut and the knee flexed lateral rotation is increased *still further* by severance of the popliteus tendon (ranging from 50 to 70) Medial rotation (B) ranges from 45 to 50 (A)

aforementioned position in relation to one another In this position, the medial femoral condyle is held in a relatively fixed position on the tibia by the posterior cruciate ligament and the tight long anterior fibers of the tibial collateral ligament. When extension is initiated the femoral condyles roll and glide on the superior surface of the tibia. As extension proceeds the medial femoral condyle is allowed less freedom than the lateral condyle, whose path of motion is controlled by the anterior cruciate ligament and the configuration of the two femoral condyles As extension approaches completion more and more posterior fibers of the tibial collateral ligament become taut. At 160° of flexion the fibular collateral ligament and the tendon of the popliteus begin to become taut thereby inhibiting more forward motion of the lateral condyle Full extension is achieved by internal rotation of the femur in the final phase the medial condyle spins and glides slightly posteriorly In this locked position, all fibers of the tibial collateral ligament, the fibular collateral ligament both cruciate ligaments and the popliteus tendon are tense also the posterior capsule and its reinforcing ligaments the arcuate and the oblique popliteal ligaments are tight, precluding motion in any plane Under normal conditions rotary motion can be achieved only by unlocking the joint, which occurs after the first 20 of flexion have been executed

The cruciates intertwine as extension advances and in complete extension they are so tightly intertwined that any medial rotation of the tibia on the femur is precluded The nature of the attachments of the cruciate ligaments prevents any abnormal displacement of the tibia on the femur in the sagittal plane In all positions, the anterior cruciate prevents abnormal forward displacement of the tibia and the posterior cruciate abnormal backward displacement Normally, in the flexion position a small amount of rotary motion and anteroposterior displacement is present

It was recorded previously that this investigation paralleled the study recorded by Brantigan and Voshell in 1941 In general, the observations noted in this work are in agreement with those of the aforementioned investigators, however, there is one exception These workers claim that after division of the tibial collateral ligament no abnormal lateral motion (abduction) of the tibia on the fixed femur occurs, either in extension or flexion In the study recorded herein abduction rocking of the tibia on the femur was noted in flexion in all intact fresh specimens the range varies from 14° to 18° when the knee is flexed 90° This observation has been recorded by Palmer and Abbott and his co-workers In addition, previous workers have failed to understand the role of the tendon of the popliteus muscle in protecting the knee joint against abnormal rotary forces this feature has been observed and recorded herein

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Affections of the Menisci

SURGICAL ANATOMY OF THE MENISCI

Comprehension of the surgical anatomy and the physiology of the menisci is essential in order that operative procedures on these structures may be performed with precision and furthermore to ensure the patient a knee capable of optimum function. It has been recorded previously that the menisci are important intra-articular structures which have reached the highest level of development in man. Although one must concede that their presence greatly facilitates normal function of the knee joint, clinical experience reveals that their removal does not preclude good function provided that no other alterations of the ligamentous and muscular apparatus of the joint exist. The menisci are crescentic disks, triangular in cross section, each covering approximately two thirds of the corresponding articular surface of the tibia (Fig. 38). In a measure they compensate for the incongruities of the articular surfaces of the femoral and the tibial condyles. Essentially they comprise dense, tightly woven collagen fibers which are arranged more loosely at their extremities. The collagen fibers and their pattern of arrangement provide the menisci with great elasticity, which can withstand compression. This feature is most prominent in children and adolescents but decreases in intensity in each successive age period. This provides an explanation for the infrequent occurrence of tears of the menisci in children and adolescents as compared with the frequency of such lesions in older individuals. The outer border of each meniscus is convex and thick and attached to the inner surface of the fibrous capsule except where the tendon of the popliteus muscle is interposed between the capsule and the lateral meniscus. In addition, the outer surface is attached loosely to the borders of the condyles of the tibia by the coronary ligaments, which are fibrous projections of the fibrous capsule connecting the peripheries of the menisci with the adjacent margin of the head of the tibia. The inner borders are concave, thin and unattached. After the age of 3, all unattached surfaces are devoid of synovialis and are avascular except for a narrow zone adjacent to their line of attachment to the fibrous capsule. The inferior surfaces are flat, articulating with the plateaus of the tibia; the superior surfaces are concave, articulating with the condyles of the femur.

Medial Meniscus and Tibial Collateral Ligament

The anatomic features of the medial meniscus which are of surgical significance are primarily the size, the shape, the attachments of the meniscus and its relation to the tibial collateral ligament. As previously noted, the medial meniscus is larger than the lateral and is often described as a segment of a larger circle. Its posterior segment is wider and thicker than the anterior, whose anterior horn often tapers gradually as it approaches its anterior site of fixation. The convex periphery decreases gradually in thickness as the thin free concave margin is approached; this change in thickness is less pronounced in the posterior segment

than in the anterior The entire circumferential border of the structure is relatively firmly attached to the fibrous capsule of the joint and through the coronary ligaments to the border of the tibia In addition the posterior horn is anchored to the posterior surface of the head of the tibia immediately in front of the attachment of the posterior cruciate ligament but behind the tibial spine. The anterior horn is attached firmly to the intercondyloid fossa of the tibia, in front of both the attachment of the anterior cruciate ligament and the anterior point of anchorage of the lateral meniscus The different modes of attachment of the anterior horn are depicted in Figure 41

Although the general configuration of the medial meniscus is more constant than that of the lateral, numerous variations may be encountered. The most significant one is unusual elongation and thinning of the anterior segment On rare occasions a discoid cartilage may be observed

The intimate relationship of the medial meniscus to the tibial collateral ligament explains in a measure the frequency of implication of both structures by a single mechanism Numerous dissections of this ligament reveal that it consists of a deep and a superficial layer The deep layer is the smaller of the two and essentially comprises thickened vertical fibers of the joint capsule It extends from the medial epicondyle of the femur to the articular margin and the medial surface of the shaft of the tibia. It fuses firmly with the periphery of the meniscus its anterior and posterior margins are continuous with the fibrous capsule.

Of greater surgical significance is the superficial layer of the tibial collateral ligament It is a flat broad triangular fibrous structure possessing great strength It overlaps the deeper layer completely and measures approximately 10 4 cm. in length. The superficial stratum of the ligament exhibits two groups of fibers the long vertical anterior fibers and the short oblique posterior fibers Its widest portion is directly over the medial meniscus (Fig 34) The mode of attachment of this ligament is of special importance. Proximally, it inserts into the femur just below the adductor tubercle and into the medial epicondyle of the femur, distally, the anterior fibers insert into the medial aspect of the shaft of the tibia 4 5 cm. below the articular margin The fibers continue downward for approximately 2 1 cm The ligament is not attached to the tibia throughout its entire length A bursa was found between the upper portion of the vertical fibers and the tibia in 94 per cent of the specimens dissected

The oblique fibers converge backward toward the joint line and fuse with the periphery of the meniscus Some of these fibers continue downward and insert in the upper border of the groove of the tendon of the semimembranosus, while others cross the tendon to reach the lower border of the groove, still other fibers are continuous with the anterior vertical fibers of the ligament.

It must be emphasized that the anterior vertical border of the superficial portion of the ligament is free and not adherent to the meniscus the space between the two structures contains loose areolar tissue and often a bursa Proximal to the joint line, the deep and the superficial fibers of the ligament blend into one fibrous structure, distal to the joint space the two layers are separated by a projection of the tendon of the semimembranosus Below this point the inferior medial genicular vessels and nerves pass between the shaft of the tibia and the ligament (Fig 36) The tendons of the gracilis and the semitendinosus and the expansion of the sartorius cross the distal end of the ligament between these structures and the ligament is interposed the bursa anserine In all degrees of flexion some portion of the ligament is taut this feature allows the medial ligament to control in a large measure abduction adduction and rotatory movements of the knee joint Also in flexion the

ligament glides backward approximately 4 mm.

From the above description of the surgical anatomy of the medial meniscus it becomes apparent that the structure is relatively firmly attached to the tibia, the capsule and the deep and the oblique posterior fibers of the tibial collateral ligament nevertheless the attachments are such that the meniscus is capable of some forward and backward motion on flexion and extension of the joint However the amount of movement is less than that exhibited by the lateral meniscus The limited excursion of the meniscus is a factor making it more vulnerable to injuries produced by abnormal rotatory forces because it is more prone to be caught and crushed by the femoral condyle Some observers are of the opinion that the narrow meniscus is less apt to be injured than the broad This is based on the premise that being narrow less rotatory force can be imposed upon it by the femoral condyles than if it were broad

Lateral Meniscus and the Fibular Collateral Ligament

The lateral meniscus exhibits more uniformity than the medial it is nearly circular, forming a large segment of a small circle Also it covers more of the articular surface of the corresponding plateau of the tibia than does the medial meniscus The anterior horn is attached to the tibia immediately in front of the intercondyloid eminence of the tibia and behind and slightly lateral to the anterior attachment of the medial meniscus. Its posterior horn inserts into the posterior aspect of the intercondyloid eminence and in front of the posterior attachment of the medial meniscus. In 53 per cent of the specimens studied a strong fasciculus is given off by the posterior cornu This structure (ligament of Wrisberg) continues upward and medially behind the posterior cruciate ligament to gain insertion into the medial condyle of the femur 20 per cent of the specimens revealed a similar structure (ligament of Humphry) passing in front of the posterior cruciate ligament (Fig 40) In addition, the posterior segment of the lateral meniscus is attached to the fascia covering the popliteus muscle which in turn blends with the fibers of the arcuate ligament Elsewhere the meniscus is free the tendon of the popliteus muscle separates it from the fibrous capsule and the deep fibers of the fibular collateral ligament The tendon of the popliteus is enveloped in synovial membrane and forms an oblique groove on the periphery of the meniscus At this point the synovial membrane is in proximity to the meniscus in fact this is the only region in the peripheries of either meniscus that such a relationship is demonstrable One is likely to encounter more variations of the lateral meniscus than of the medial the incidence of discoid menisci observed in the lateral side of the joint is far greater than that noted in the medial A common variation is unusual widening of the central portion of the structures as compared with its anterior and posterior segments

The relationship of the lateral meniscus to the fibular collateral ligament is of particular surgical significance because it allows the meniscus a relatively large range of movement Dissection of the fibular collateral ligament reveals that it comprises a deep and a superficial portion This feature has been noted by other workers The deep component which is the smaller of the two is attached proximally to the lateral epicondyle of the femur and distally to the medial aspect of the upper surface of the head of the fibula and to the styloid process The tendon of the popliteus with its synovial sheath separates the ligament from the lateral meniscus Its posterior border blends with the fibers of the fascia covering the popliteus muscles and some of the fibers contribute to the formation of the arcuate ligament It was recorded previously that

the posterior segment of the lateral meniscus is attached to the upper portion of the arcuate ligament, the popliteal fascia and the fibrous capsule of the joint The superficial portion (long external ligament) is a stout fibrous cord, it inserts above into the lateral epicondyle of the femur and below into the upper surface of the head of the fibula lateral to the deep fibers Separation of the deep and the superficial fibers can be achieved readily by sharp dissection Proximal to the styloid process of the fibula the tendon of the biceps femoris winds around the superficial fibers counterclockwise, occupying a position between the two layers of the fibular collateral ligament In flexion this ligament is relaxed hence, it in no way influences abduction, adduction or rotatory movements of the knee joint. This feature is in contradistinction to the controlling influence of the tibial collateral ligament in the movements enumerated Some portion of the medial ligament is taut in all degrees of flexion therefore, it effects considerable control on all movements of the joint.

From the above observations, it becomes apparent that the lateral meniscus is capable of considerable forward and backward movement. Complete detachment of the lateral meniscus from the fibular collateral ligament is the most important single feature allowing freedom of motion to the ligament hence, it is less prone to be subjected to injurious rotatory forces This is in contradistinction to the less mobile medial meniscus which because of its limited range of movement, is more vulnerable to injury by the same mechanisms In addition when the tibia is rotated inward with the knee flexed, the popliteus muscle via the arcuate ligament draws the posterior segment of the meniscus backward, thereby preventing the structure from being caught between the condyle of the femur and the plateau of the tibia. Backward displacement of the meniscus is further enhanced by the ligaments of Wrisberg and Humphry

ROLE OF MENISCI IN MECHANICS OF THE KNEE JOINT

The importance of the menisci in the over all mechanics of the human knee joint is reflected in their size as compared with those in lower animals In the study of the mechanics of the knee joint it was pointed out that menisci move forward in extension and backward in flexion The motion is controlled by the movements of the femoral condyle and occurs between the superior surfaces of the menisci and the condyles of the femur (Although the menisci move backward and forward on the tibia, together with the tibia they move on the femur in flexion and extension of the knee joint) It becomes apparent that motion in the sagittal plane (flexion and extension) primarily occurs in the plane between the femoral articular surfaces and the superior surfaces of the menisci Concurrently with the onset of flexion, the lateral meniscus moves backward, the greatest amount of displacement occurs after 5° to 7° of flexion have been achieved The average amount of backward displacement in the author's study was 9 mm It is of interest that during the initial phase of flexion the medial meniscus remains stationary backward displacement occurs only after 17° to 20° of flexion have been consummated The average amount of displacement noted was 3 mm, which is considerably less than that of the lateral meniscus After 70° of flexion no further displacement of the medial meniscus is discernible beyond this arc the posterior segment of the structure is gripped firmly between the posterior flare of the femoral condyle and the tibial plateau On the other hand, backward displacement of the lateral meniscus continues until full flexion has been achieved If hyperflexion is continued beyond this point, the posterior segment of

the meniscus tends to slide backward over the posterior flare of the external condyle of the femur, thereby avoiding compression between the condyle of the femur and the articular surface of the tibia. Compression of the posterior segment may occur only in extreme hyperflexion, when the structure together with the corresponding portion of the medial meniscus the posterior capsule and the tendinous origins of the medial and the lateral heads of the gastrocnemius muscle tends to check further flexion Hyperflexion is checked also by both cruciate ligaments which become very taut, and the bony configuration of the condyles of the femur It must be understood that the observations made relative to compression of the menisci have been made on knee joints not bearing weight As will be noted subsequently some compression of the fibrocartilage does occur when the joint is bearing weight or subjected to abnormal stresses which cause compression of the articular cartilage of the femur and the tibia. It may well be that in the living because of the aforementioned feature, the range of motion of both menisci in flexion and extension is less than that described above

In flexion the ligaments of Wrisberg and Humphry assist in pulling the meniscus backward and prevent anterior displacement of the structure during abnormal flexion and rotatory movement which would tend to trap the meniscus between the femur and the tibia All these factors play an important role in making the posterior portion of the lateral meniscus less vulnerable to injury The medial meniscus does not possess such anatomic safeguards

In flexion the knee unlocks the fibular collateral ligament is relaxed and the tibial collateral ligament the cruciate ligaments and the capsule are less tense allowing a small amount of abduction adduction and rotation In rotatory movements the menisci move with the condyles of the femur The greater range of excursion of the lateral meniscus as compared with that of the medial is made possible by the wider arc described by the lateral femoral condyle the axis of rotation is near the medial femoral condyle hence the medial condyle must describe a smaller arc than the lateral In the light of these observations one must conclude that rotatory movements in the knee joint occur in the plane between the articular plateaus of the tibia and the inferior surfaces of the menisci As pointed out by Smillie the frequency of lesions of the inferior surface of the menisci resulting from abnormal forces acting in the plane between the tibia and the inferior surfaces of the menisci substantiate the aforementioned premise

As the position of complete extension is approached from one of flexion abduction adduction and rotatory movements decrease progressively in range until no movements exist when full extension is achieved the knee has performed the screw home maneuver and is now locked in extension Since lateral and rotatory movements are not possible an injury to the meniscus alone cannot occur however it is possible to inflict injury to the menisci if the ligamentous and the osseous elements are disrupted such as a rupture of a collateral ligament or a fracture of the condyles of the tibia.

In complete extension in nonweight bearing joints the menisci fit snugly in their respective grooves in the corresponding femoral condyles of the femur but they are not compressed Even with hyperextension it is not possible to compress the structures between the condyles of the femur and the tibial plateaus The structures compressed are the lateral expansions of the infrapatellar fat pad This observation was recorded by Fisher and has been confirmed by the author in the study of several hundred specimens If one studies the superior surfaces of the lateral expansions of the fat pad the imprints of the femoral condyle resulting from compression in extension and hyperextension are readily demonstrable However in weight bearing positions particu

larly such as standing, some compression of the articular cartilage of the femur and the tibia occurs, this in turn enables the menisci to share in weight bearing, hence, some compression of the fibrocartilage must occur The mechanism of this function is discussed below

Functions of the Menisci

The menisci compensate for the gross incongruity between articular surfaces of the tibia, thereby adding in a small measure to the stability of the knee joint The attachment of the capsule and the synovialis to their circumferential borders precludes displacement of these structures into the joint otherwise they would be sucked into the joint and nipped by the articular surfaces.

A very important function of the menisci was noted by MacConaill In his study on the function of intra articular fibrocartilages he proposed that the menisci minimized friction by the formation and the maintenance of a thin, wedge-shaped film of synovia between the opposing articular surfaces In the case of the menisci in the knee joint, this function is made possible by virtue of the triangular configuration of the structures and by their close relationship to both articular surfaces

Finally the menisci also assume some weight bearing function Fairbank has shown that as the result of normal weight bearing or from sudden strains, compression of the articular cartilage occurs With an increase in compression the menisci are forced centrifugally a force which is resisted by the rising tension in the elastic fibrocartilages this tension is made possible by the attachments of the ends of the menisci It becomes apparent that the increase in the circumferential tension in the menisci parallels the increase in joint compression Inasmuch as this tension resists extrusive forces the menisci are made to share in some of the weight bearing thereby acting as buffers or shock absorbers and protecting the articular surfaces. The protective nature of the menisci has been amply demonstrated experimentally by many workers King (1936) observed the degenerative changes that occurred in the articular hyaline cartilages of dogs after partial or complete meniscectomies The alterations were roughly proportional to the size of the segment excised, the maximum intensity in the changes was noted in cases with complete meniscectomy In the human, Fairbank (1948) pointed out that the changes that occur after meniscectomy are ridge formation, narrowing of the joint space and flattening of the femoral condyle he proposed that these alterations were the result of the loss of the weight bearing function of the meniscus Although clinical experience would lead one to believe that meniscectomy is an innocuous procedure, it becomes apparent that the knee joint is deprived of a very important constituent when the meniscus is removed, and the articulation is predisposed to osteo-arthritic changes over a long term period

NUTRITION OF MENISCI

It has been stated previously that during the development of the menisci, the structures are infiltrated throughout by a rich mesh of blood vessels. After the third year of life when the child has assumed the upright position vascularity of the menisci is diminished only that portion of the fibro-elastic cartilages adjacent to the coronary ligaments and the capsules is permeated with blood vessels The blood vessels come from the capsule and the synovial membrane which is reflected for a short distance over the superior and the inferior surfaces of the menisci close to their peripheral attachment to the capsule The avascular central and concave portions of menisci are dependent entirely for nutrition upon the synovia which is adequate to provide nourishment for a normal meniscus but inadequate to achieve repair of lesions in the avascular zones This feature has been sub-





FIG 80 (*Left*) Tear through the avascular zone of a medial meniscus this type of lesion never heals.

FIG 81 (*Right*) Tear through peripheral zone of a medial meniscus healing by fibrous tissue has occurred This is an extremely rare lesion

FIG. 82 (*Bottom*) (A *Left*) Longitudinal tear of the posterior segment extending to its tibial attachment a frustrated attempt to repair the defect is discernible (B, *Bottom*) Inferior view of the same specimen. Observe the maceration of the inferior surface.





stantiated many times experimentally in animals and clinically in humans

BEHAVIOR OF TORN MENISCI

The work of King (1936) conducted on dogs established conclusively the reparative response of lesions in different portions of the menisci The conclusions derived from this investigation are of special significance because they are applicable in every respect to the lesions encountered in the menisci of man This has been confirmed clinically by many observers, including the author The experiments indicated four conclusions

1 Tears which are limited to the semilunar cartilage probably never heal.

2 A torn meniscus can be healed by connective tissue if the tear communicates with the synovial membrane laterally

3 A complete transverse or oblique tear results in some separation of the fragments, but the intervening space fills in with connective tissue arising from the synovial membrane This connective tissue is quite firm in 3 weeks, which suggests the length of time necessary for complete fixation in these cases

4 If the meniscus is partially torn from its peripheral attachment it heals in normal anatomic position without difficulty

The clinical import of the first conclusion becomes apparent when one realizes that the majority of lesions in man occur within the avascular portions of the meniscus at a distance from its peripheral attachment (Fig 80) Longitudinal tears through the *peripheral zone* do occur, but clinical investigation reveals that they are exceedingly rare also that nature attempts to heal lesions in this region can be proved by study of some of the specimens excised in toto at operation (Fig 81)

The second conclusion has little practical significance because tears which communicate with the synovial membrane are encountered rarely Transverse or oblique tears implicating the convex periphery while the remaining portion of the meniscus remains intact have not been encountered It must be conceded that on occasion longitudinal tears involving the posterior segment may extend to the attachment of the synovial membrane In these instances a frustrated attempt to repair the defect may be discernible (Fig 82)



Fig 83 Old complete transverse tear which has healed by fibrous tissue (constricted portion) Theoretically, healing has been achieved by extension of connective tissue from the periphery This lesion is extremely rare (*Left*, superior surface, *right*, inferior surface)

From a clinical viewpoint, the third conclusion indicates the period of time (3 weeks) that the limb should be immobilized and spared weight bearing if healing of a complete transverse tear is to be achieved In the human complete transverse tears with separation do occur, but their incidence is very small when compared with the frequency of incomplete transverse and oblique tears extending from the thin concave margin for varying distances into the avascular substance of the meniscus. Cases of complete transverse tears extending laterally to the synovial membrane which have healed by fibrous tissue have been recorded the author has encountered one case It was interesting to note the configuration of the healed meniscus at the site of repair the meniscus was *constricted*, narrowed and rounded as though a rubber band had been placed tightly around it (Fig 83)

King's fourth conclusion provides a scientific basis for the conservative management

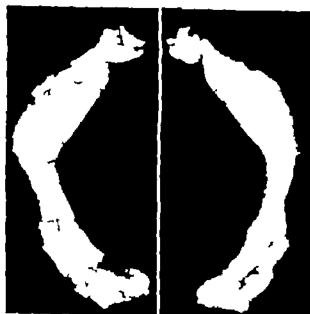


FIG. 84 Regenerated anterior segment of a medial meniscus The patient had the first meniscectomy 15 years prior to the second Observe the difference in the breadth of the anterior and the posterior segments. Microscopic examination revealed that the anterior *half* comprised dense fibrous tissue (*Left* superior surface *right* inferior surface)

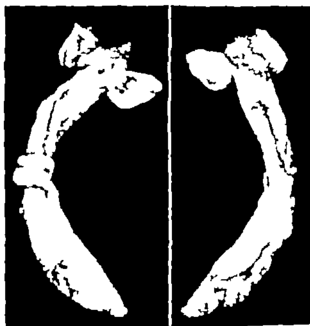


FIG 85 Regenerated medial meniscus. *The inferior surface (left)* shows two pedunculated portions of the meniscus which have been displaced beneath the structure (*Right*) The superior surface shows a longitudinal tear in the posterior segment and maceration of the posterior attachm nt

of a specific group of tears of the menisci Experimentally and clinically it can be *demonstrated that peripheral detachments* of the meniscus may heal in normal anatomic positions The mobility of the lateral meniscus renders this structure more vulnerable to this type of tear than its medial counterpart in which the lesion is encountered rarely In order to assure normal restoration of the anatomy following partial tearing of the peripheral attachment of a meniscus the limb must be immobilized for a sufficient period of time to allow adequate *healing and during this period* no weight bearing must be permitted Cases are encountered in which the interval between the convex margin of the meniscus and its peripheral site of attachment is bridged by elongated fibrous tissue making it apparent that inadequate immobilization failed to permit firm adherence of the fibrocartilage to the capsular tissues. In other instances this same factor is responsible for complete failure of any healing at the site of periph*eral tearing the convex border of the me*niscus is smooth free and hypermobile It is exceedingly difficult to make a positive diagnosis of a tear at the site of peripheral attachment of a meniscus in fact it is impossible to distinguish this lesion from a longitudinal tear of the posterior segment It becomes obvious that if conservative management is selected as the method of choice the selection is made with the mental reservation that the diagnosis of a periph*eral tear may or may not be correct*

REGENERATION OF MENISCI

It is now accepted generally that following partial excision or total extirpation of a meniscus replacement of the structure occurs by ingrowth of connective tissue from the synovial membrane The process by which this is accomplished parallels in every respect that observed in experimental animals. Following excision of an entire *meniscus grossly* the new structure resembles closely the normal meniscus in configuration the peculiarities of the medial

and the lateral meniscus are clearly distinguishable in the reproduction Microscopically the false meniscus is readily discernible from the normal fibrocartilage It comprises densely packed fibrous tissue, the absence of cartilage cells is a conspicuous feature.

As Smillie pointed out, the regenerated meniscus exhibits some characteristic features which set it aside from the normal Its surface is smooth, glistening and of a whiter color than the normal structure It tends to be elongated thin and narrow and does not have the sharp, delineated margins of the triangular normal fibrocartilage Instead its concave margin is thin and may be irregular in outline Also, the structure does not exhibit the mobility noted in the normal meniscus, this is explained by the firm attachment of its convex border to the joint capsule.

The above features of a regenerated meniscus are even more conspicuous when only the anterior portion of normal fibrocartilage has been removed and replaced by fibrous tissue (Fig 84) One readily notes the contrast in color in the two segments the new structure is thinner and lacks the uniformity of the normal segment The site of fusion between the two is often narrow and limited to the peripheral border where adequate blood supply is present.

The experimental work of King disclosed that following extirpation of the menisci degenerative changes ensued in the articular cartilage of the femur and the tibia The intensity of the alterations was roughly proportional to the size of the segment excised being greatest in the instances in which total meniscectomy was done This observation leads one to conclude that one of the functions of the menisci is to protect the articular surfaces from undue stresses. Fairbank noted similar changes in the knee joint of humans following meniscectomy It becomes apparent that the replica does not afford the same protection to a knee joint as the normal meniscus (Figs. 85 86 87)

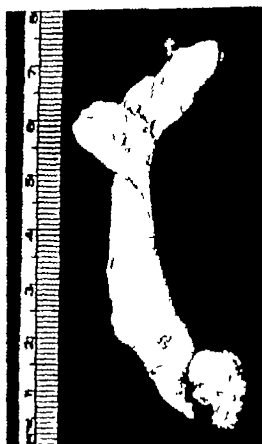


Fig 86 Regenerated medial meniscus (superior surface) Observe a longitudinal tear in the posterior horn The pedunculated tag projected at the periphery behind the posterior margin of the tibial collateral ligament

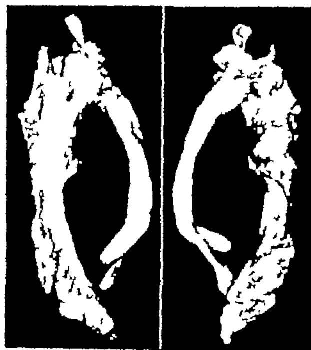


Fig 87 Regenerated medial meniscus. Note the long longitudinal tear extending into both the anterior and the posterior segments. (*Left*, inferior surface *right* superior surface)

TRAUMATIC LESIONS OF THE MENISCI

Mechanism

Numerous theories have been set forth in an attempt to explain the mechanism which produces the varied lesions of the menisci found at operation The intricate mechanics *and the many factors which must be considered in the analysis of the normal and* the abnormal movements of the knee joint are responsible for the lack of agreement between many of the premises proposed However there are some points which are acceptable to most observers It has been recorded previously that it is impossible to injure only the fibrocartilages when the knee is locked in the position of extension.

If the forces are of sufficient violer produce lesions of the menisci with the extended, the lesions are always in con tion with rupture of one of the coll ligaments or the opposite tibial co Lateral and rotatory motions at the kn only possible in flexion Of special s cance is the relation of the menisci t *tibial condyles and of the femoral t* tibial condyles when flexion or extens superimposed upon the knee joint fi internal or external rotation One can onstrate the following points readi fresh specimens With the lower leg in internal or external rotation if f and extension are performed one note the normal relationship of the articula faces of the femoral condyles to th

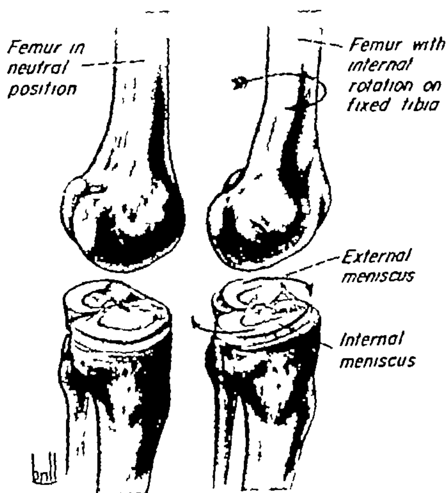


FIG 88 During rotation of the femur on the fixed tibia the medial femoral condyle sweeps the internal meniscus backward and inward ... is carried backward and centrifugally

the tibia is altered, resulting in considerable incongruity The extent of the anteroposterior motion of the menisci is appreciably lessened, the fibrocartilages remain fixed to the tibia and move with it on the femoral condyles The femoral condyles tend to sweep the menisci toward the periphery, creating extrusive forces. It becomes obvious that if flexion and extension are added while the knee is held in internal or external rotation the menisci are subjected to abnormal forces which make them vulnerable to injury In summation the factors responsible for injury to the menisci are flexion rotation, weight bearing and above all, failure to restore normal congruity between the femoral and the tibial condyles during flexion and extension Study of dissected fresh knee joints indicates that lesions of the menisci are produced by the mechanism about to be described, this mechanism affords an explanation, partially on theoretical grounds, for the frequent implication of the posterior segments

MECHANISM OF INTERNAL ROTATION OF FEMUR (TIBIA FIXED AND KNEE FLEXED)

With the knee flexed and the tibia fixed, when the femur is rotated internally the medial condyle sweeps the internal meniscus as a whole backward and slightly inward but the posterior segment (that portion between the posterior oblique fibers of the tibial collateral ligament and the attachment of the posterior horn) is carried directly backward or centrifugally (Fig 88) This act is resisted by the capsular, the anterior and the posterior bony attachments of the meniscus its fusion to the posterior oblique fibers of the tibial collateral ligament and by the rising tension in the stretched and elastic fibrocartilage This tension is greatest in the posterior segment between its attachment to the tibial collateral ligament and its posterior attachment the circumferential tension in this sector rises rapidly Because of the incongruity between the femoral and the tibial condyles, especially in flexion and rotation of the joint, the posterior flare of the medial condyle is not capable of maintaining even pressure on the displaced and stretched posterior segment Hence as it sweeps inward the condyle releases the pressure from the center of the posterior segment, which, being under severe circumferential tension, snaps into the interior of the posterior compartment of the joint, if at this point the knee is extended, the segment is crushed between the femoral condyle and the tibial plateau or torn from its peripheral attachment.

During this maneuver the lateral femoral condyle sweeps the lateral meniscus centrifugally and forward Because of the mobility of the lateral fibrocartilage and because of the wide arc that the femoral condyle describes in executing internal rotation, the meniscus is carried forward an appreciable distance, so that tension in any portion of the structure is never equal to that in the posterior segment of its medial counterpart. Instead severe traction is made on its posterior capsular attachment, pulling the posterior segment into the posterior compartment of the joint, if the joint is extended suddenly the segment may be trapped between the articular surfaces of the femur and the tibia The relative infrequency of this lesion as compared with lesions of the posterior segment of the medial meniscus can be explained by the freedom of movement that the lateral fibrocartilage possesses and also by virtue of its attachment posteriorly to the popliteus fascia and the ligaments of Wrisberg and Humphry, which act as checkreins to forward displacement and tend to pull the structure posteriorly before it can be trapped

This same mechanism may produce transverse tears (partial or complete) of the meniscus Internal rotation of the femoral condyles tends to stretch the relatively fixed fibrocartilage. This act places the greatest strain on the concave margin of the meniscus hence a transverse tear may result Inasmuch as the lateral meniscus is a large

TRAUMATIC LESIONS OF THE MENISCI

Mechanism

Numerous theories have been set forth in an attempt to explain the mechanism which produces the varied lesions of the menisci found at operation. The intricate mechanics and the many factors which must be considered in the analysis of the normal and the abnormal movements of the knee joint are responsible for the lack of agreement between many of the premises proposed However there are some points which are acceptable to most observers It has been recorded previously that it is impossible to injure only the fibrocartilages when the knee is locked in the position of extension

If the forces are of sufficient vio produce lesions of the menisci with extended, the lesions are always in c tion with rupture of one of the c ligaments or the opposite tibial Lateral and rotatory motions at the only possible in flexion Of specia cance is the relation of the menis tibial condyles and of the femora tibial condyles when flexion or ext superimposed upon the knee joint internal or external rotation One c onstrate the following points re fresh specimens With the lower in internal or external rotation, f and extension are performed one n the normal relationship of the artic faces of the femoral condyles to

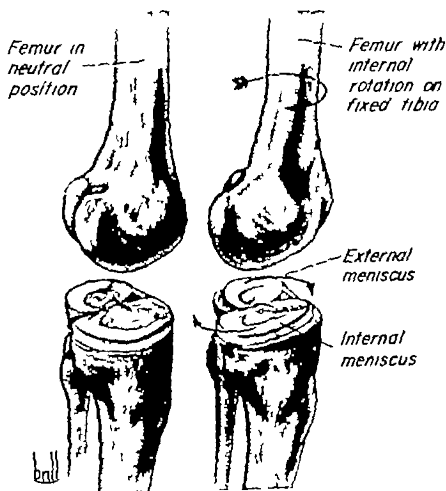


Fig 88 During rotation of the femur on the fixed tibia the medial femoral condyle sweeps the internal meniscus backward and inward the posterior segment is carried backward and centrifugally

the tibia is altered, resulting in considerable incongruity The extent of the anteroposterior motion of the menisci is appreciably lessened, the fibrocartilages remain fixed to the tibia and move with it on the femoral condyles The femoral condyles tend to sweep the menisci toward the periphery, creating extrusive forces. It becomes obvious that if flexion and extension are added while the knee is held in internal or external rotation the menisci are subjected to abnormal forces which make them vulnerable to injury In summation the factors responsible for injury to the menisci are flexion rotation, weight bearing and above all failure to restore normal congruity between the femoral and the tibial condyles during flexion and extension Study of dissected fresh knee joints indicates that lesions of the menisci are produced by the mechanism about to be described, this mechanism affords an explanation, partially on theoretical grounds, for the frequent implication of the posterior segments

MECHANISM OF INTERNAL ROTATION OF FEMUR (TIBIA FIXED AND KNEE FLEXED)

With the knee flexed and the tibia fixed, when the femur is rotated internally the medial condyle sweeps the internal meniscus as a whole backward and slightly inward but the posterior segment (that portion between the posterior oblique fibers of the tibial collateral ligament and the attachment of the posterior horn) is carried directly backward or centrifugally (Fig 88) This act is resisted by the capsular, the anterior and the posterior bony attachments of the meniscus its fusion to the posterior oblique fibers of the tibial collateral ligament and by the rising tension in the stretched and elastic fibrocartilage This tension is greatest in the posterior segment between its attachment to the tibial collateral ligament and its posterior attachment the circumferential tension in this sector rises rapidly Because of the incongruity between the femoral and the tibial condyles, especially in flexion and rotation of the joint, the posterior flare of the medial condyle is not capable of maintaining even pressure on the displaced and stretched posterior segment. Hence as it sweeps inward the condyle releases the pressure from the center of the posterior segment, which, being under severe circumferential tension, snaps into the interior of the posterior compartment of the joint If at this point the knee is extended, the segment is crushed between the femoral condyle and the tibial plateau or torn from its peripheral attachment.

During this maneuver the lateral femoral condyle sweeps the lateral meniscus centrifugally and forward Because of the mobility of the lateral fibrocartilage and because of the wide arc that the femoral condyle describes in executing internal rotation, the meniscus is carried forward an appreciable distance, so that tension in any portion of the structure is never equal to that in the posterior segment of its medial counterpart. Instead, severe traction is made on its posterior capsular attachment, pulling the posterior segment into the posterior compartment of the joint, if the joint is extended suddenly the segment may be trapped between the articular surfaces of the femur and the tibia The relative infrequency of this lesion as compared with lesions of the posterior segment of the medial meniscus can be explained by the freedom of movement that the lateral fibrocartilage possesses and also by virtue of its attachment posteriorly to the popliteus fascia and the ligaments of Wrisberg and Humphry, which act as checkreins to forward displacement and tend to pull the structure posteriorly before it can be trapped

This same mechanism may produce transverse tears (partial or complete) of the meniscus. Internal rotation of the femoral condyles tends to stretch the relatively fixed fibrocartilage This act places the greatest strain on the concave margin of the meniscus hence, a transverse tear may result Inasmuch as the lateral meniscus is a large

segment of a small circle its concave margin is subjected to greater tearing forces than the medial meniscus which is a small segment of a large circle this explains the higher incidence of transverse tears in the lateral structure

MECHANISM OF EXTERNAL ROTATION OF THE FEMUR (TIBIA FIXED AND KNEE FLEXED)

With the knee flexed and the tibia fixed when the femur is forcibly rotated externally the opposite of the mechanism described above is produced This mechanism is more apt to cause peripheral tears of the posterior segment of the medial meniscus and transverse tears of the lateral meniscus Also, the recoil mechanism is less prone to inflict injuries to the posterior segment of the lateral meniscus because it is resisted by the action of the popliteus muscle and the ligaments of Wrisberg and Humphry

From the descriptions of the aforementioned mechanisms it becomes apparent that the posterior segments of the fibrocartilages are implicated most frequently and theoretically a longitudinal tear is the most common lesion to be expected This is substantiated by clinical observations The length, the depth and the position of the initial tear are variable and depend on the position of the posterior segment in relation to the femoral and the tibial condyles at the time extension is superimposed also it depends upon the severity of the force producing the lesion In addition one can readily conceive how pathologic processes at the periphery of the convex border of the meniscus may influence the frequency and the type of lesion such disorders as cysts or bursae causing fixation of the fibrocartilages tend to restrict their freedom of movement and render them more vulnerable to trappings Forces of minor intensities may produce incomplete longitudinal tears of the posterior segments or may core their inferior surfaces forces of greater intensities may produce complete tears, some of which may extend far anteriorly and produce the so-called bucket handle lesions, which cause true locking of the joint if the medial segment is displaced to the inner side of the corresponding femoral condyle In cases of lesions limited to the posterior segments a reversal of the recoil mechanism described above may force the structure into its normal anatomic position after trapping so that true locking of the joint does not occur

Varieties of Traumatic Lesions of Menisci

From a survey of the pathologic specimens removed at operation and correlation of the observation noted with the mechanism of production of the different lesions previously described the numerous varieties of the lesions encountered can be placed in the following categories (1) longitudinal tears (2) transverse tears and oblique tears, (3) combined lesions (4) cysts of the menisci (5) lesions of discoid menisci and (6) lesions of both menisci (Tables 3 4 and 5)

TABLE 3 MENISCECTOMIES

Medial meniscus (uncomplicated)		272
Medial meniscus (complicated)		42
Lateral meniscus (uncomplicated)		127
Lateral meniscus (complicated)		66
Total		507
Male		465 (91.8%)
Female		42 (8.2%)
Cystic degeneration		48
Congenital discoid menisci		18
Regenerated menisci		13
Medial	10	
Lateral	3	
Normal menisci		29
Medial	23	
Lateral	6	

Of 358 cases studied for presence or absence of locking	
Locking occurred at the original injury in	19
Subsequent locking occurred in	26%
No history of locking in	55%

TABLE 4 CYSTS OF MENISCI

Lateral meniscus	40
Medial meniscus	8
Total	48
Male	34
Female	14
Age	17 to 58 years
Average age	26 5 years
Specific history of trauma	
Direct trauma to knee	26%
Twist of knee	22%
No history of specific trauma	52%

Based on 507 meniscectomies

TABLE 5 DISCOID MENISCI

Primary type	10
Intermediate type	3
Infantile type	5
Total	18
Lateral	17
Medial	1
Ages	6 to 43 years
Right side	10
Left side	8

Note Six of these structures appeared normal. However 2 of the 6 exhibited hypermobility 2 other cases were detached completely

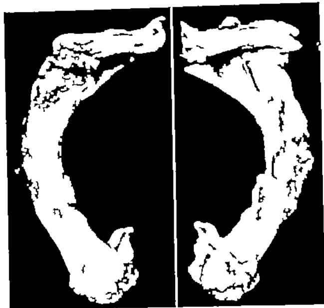


FIG 89 Note the numerous longitudinal incomplete, ribbonlike tears on the inferior surface of the posterior segment. This is evidence of repeated trappings of the posterior horn (*Left* superior surface *right* inferior surface medial meniscus)

LONGITUDINAL TEARS

Tears Involving Posterior Segment. These lesions are observed most frequently in the posterior segment of the medial meniscus They may be incomplete or complete, the latter penetrating the entire thickness of the fibrocartilage (Fig 89) They may or may not extend beyond the convex periphery Incomplete tears are encountered more frequently on the inferior than on the superior surface. Some specimens may exhibit numerous parallel incomplete tears on the inferior surface indicating that the structure was repeatedly crushed between the femoral and the tibial condyles (Fig 90) Single tears limited to the posterior segment are not capable of producing true

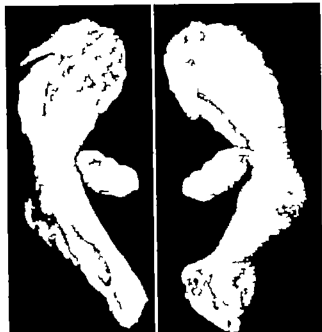


FIG 90 Observe the complete longitudinal tear of the posterior segment and multiple scorings of its inferior surface (*Left* inferior surface, *right* superior surface, medial meniscus)



Fig 91 Observe the pronounced hy pertrophy of the inner portion of the longitudinal tear in the posterior seg ment. (*Left* superior surface *right* in ferior surface medial meniscus)

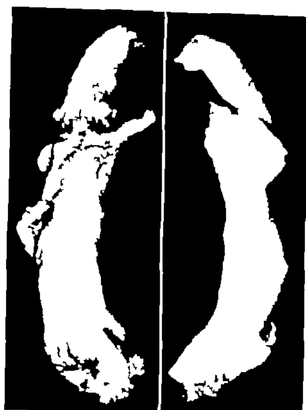


Fig 92 The inner portion of the tear has twisted upon itself and lies on the superior surface of the posterior segment. (*Left* inferior surface *right* superior surface medial meniscus)

king of the joint but they do give rise to feeling of instability and incidents of ing way or buckling of the knee joint ticularly when the patient is walking on even ground In addition single lesions this type predispose to repeated incidents trapping of the posterior segment hence *ducing multiple tears Not infrequently* nounced hypertrophy of the inner por 1 of the tear is demonstrable (Fig 91) is increase in size is an added factor mak the posterior segment more vulnerable recurrent trappings Varying alterations y be discernible in the ribbonlike strands tissue comprising the multiple tears. ne exhibit evidence of superimposed lon



Fig 93 The inner portion of the longitudinal tear has been divided transversely note that the ends are bulbous and smooth (*Left* inferior surface *right* superior surface medial meniscus)



Fig 94 No tear is noted in the posterior segment its peripheral attachment was stretched severely, allowing the segment to be displaced into the center of the joint. (*Left* superior surface *right* inferior surface, medial meniscus)

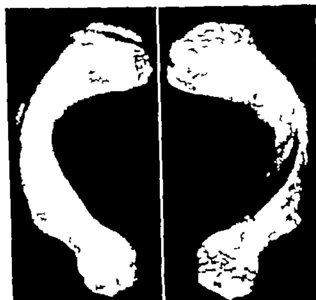


Fig 95 Note the small incomplete longitudinal tear at the peripheral attachment of the posterior segment. (*Left* inferior surface *right* superior surface medial meniscus)



Fig 96 Oblique tear through posterior segment of a medial meniscus, the surfaces oppose one another like the blades of scissors. (*Left* superior surface, *right* inferior surface)

gitudinal tears, others are twisted in their longitudinal axis, and still others are thinned, while some may be hypertrophied (Fig 92) Occasionally the longitudinal strips are divided transversely, and the severed ends may become smooth, rounded and even bulbous in shape (Fig 93) Posterior segments showing evidence of recurrent trappings invariably reveal advanced maceration on their inferior surfaces This is explained readily when one visualizes the fibrocartilage caught between the femoral and the tibial condyles being ground on the tibial plateau by the rotating force of the femur to which is added the downward thrust of weight bearing In some specimens it is interesting to note the extensive complications on the inferior surface as compared with the superior surface of the fibrocartilage indicating that the structure moves with the femur on the tibia when the lesions occur

Longitudinal tears or stretching of the



FIG 97 (*Left*) Medial meniscus, inferior surface. Old longitudinal tear of the posterior segment with fresh extension into the anterior segment resulting in locking of the joint. Note the small transverse tear in the central portion.

FIG 98 (*Right center*) Extensive longitudinal tear close to concave margin Observe that the line of cleavage is slightly oblique. This is a recent extension of an old tear it extends beyond the tibial collateral ligament This lesion did not produce true mechanical locking (*Left* superior surface *right* inferior surface medial meniscus)

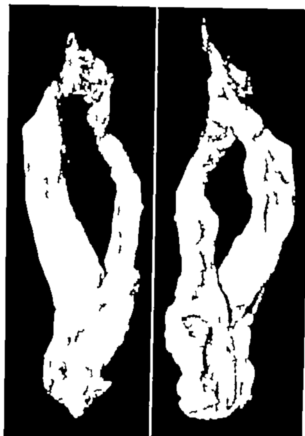




FIG 99 Longitudinal tear traverses the posterior horn and extends far into the anterior horn Posterior segments exhibit evidence of repeated trappings. (*Left* inferior surface *right* superior surface medial meniscus)

peripheral attachments of the posterior segment are a concomitant finding of longitudinal tears in its substance per se Occasionally the lesions occur without a longitudinal tear in the fibrocartilage These lesions may be of sufficient severity to allow the posterior segment to be displaced into the center of the joint Generally they occur more frequently on the lateral side but may occur on the medial (Fig 94)

Lesions limited to the peripheral attachments are relatively rare One erroneously may interpret a longitudinal tear of the pos

terior segment close to its convex periphery as a tear in the peripheral attachment (Fig 95) The tear may traverse an oblique plane, the resulting surfaces opposing one another like the blades of scissors The tear on the superior surface may be close to the periphery of the meniscus and in this position may escape detection The tear on the inferior surface is usually near the center of the posterior segment (Fig 96) Traction on the ends of the fibrocartilage readily visualizes this lesion This type of lesion is produced by the grinding rotatory action of the femur on the head of the tibia

In two instances the posterior horn was found displaced into the center of the joint. In each case a small strip of the convex periphery of the fibrocartilage still retained its attachment to the capsule and to the posterior nonarticulating surface of the tibia

Extensive longitudinal tears may be responsible for mechanical locking when the central portion of the meniscus is displaced into the intercondylar notch in proximity to the cruciate ligaments (bucket handle tears) The lesion may be an extension of an old tear of the posterior segment or it may be the result of a single injury (Fig 97) The position of the initial fracture may vary it may be near the center of the fibrocartilage or close to the convex or the concave margins (Fig 98) Generally, the line of cleavage is not in the vertical plane but is in a slightly oblique plane. It extends for varying distances anterior to the collateral ligament of the affected side In some instances the tear traverses the attachments of the anterior or the posterior cornu (Fig 99) As Smillie points out, locking occurs only when the tear with its central portion displaced into the interior of the joint, extends beyond the collateral ligament for a sufficient distance so that its anterior limit acts as a mechanical block to extension of the femur (Fig 97) If the tear runs far into the anterior segment locking will not occur because the femur can be extended readily (Fig 98) Not infrequently, extensive bucket handle tears are encountered in which the central portion is fixed to the structures in the intercondylar notch These patients present symptoms of internal derangement of the joint, but true mechanical locking does not occur (Fig 100) Once a long longitudinal tear is produced, both the central and the peripheral portions are vulnerable to repeated trappings which may result in a bizarre combination of tears Numerous alterations may occur in both portions but more in the central dislocated segment. If it remains in a fixed position in the intercondylar notch hypertrophy of the entire portion may occur On the other hand, if the central portion is caught repeatedly between the articular surfaces it may be divided transversely or longitudinally In cases of transverse division of the central portion, the ends may become hypertrophied and even bulbous in nature or, as the result of friction they may become thin and narrow and in some instances may disap-

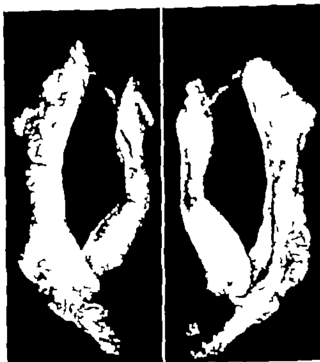


Fig 100 Old complete longitudinal tear, medial meniscus. The central portion was fixed in the region of the intercondylar notch no incidence of true locking occurred in this case. (*Left*, superior surface, *right*, inferior surface)



Fig 101 Old complete longitudinal tear The peripheral portion has been rotated on its longitudinal axis and has caused a palpable swelling on the medial aspect of the knee joint Note the multiple longitudinal tears on the inferior aspect of the fibrocartilage. (*Left* superior surface *right* inferior surface)



Fig 102 Old longitudinal tear with superimposed recent extension into the anterior segment The tear splits the fibrocartilage obliquely Observe the small transverse tear on the concave margin of the central portion (*Left* superior surface *right* inferior surface medial meniscus)



Fig 103 Extensive longitudinal tear extending far into the anterior segment. The peripheral segment together with the central segment, was found displaced into the center of the joint. Observe that both segments exhibit small transverse tears the inferior surface is scored severely (*Left* superior surface *right* inferior surface medial meniscus)

pear completely Generally the severity of the lesions on the inferior surface of the meniscus are far more pronounced than those on the superior surface Both peripheral and central portions may exhibit multiple incomplete and complete superimposed longitudinal tears together with complete or incomplete transverse tears as a rule the central portion is affected more severely Pedunculated tabs resulting from transverse division of segments of a longitudinal tear do not cause mechanical locking but they are responsible for buckling or incidences of giving way of the knee joint (Figs 101 104)

Tear Involving the Anterior Segment. Isolated lesions of the anterior segment are rare when compared with the high incidence encountered in the posterior segment. They implicate the lateral meniscus more frequently than the medial particularly if the natural free excursion of the lateral structure is restricted by some pathologic proc



FIG 104 Multiple longitudinal tears The largest tear was the original lesion, the central portion has undergone hyper trophy and exhibits two superimposed smaller and more recent longitudinal tears. A detached portion of one of the strips of cartilage was found lying in the intercondylar notch. The central portion was fixed to the structures in the notch hence no true mechanical locking oc curred in this instance. (*Left* superior surface *right*, inferior surface)

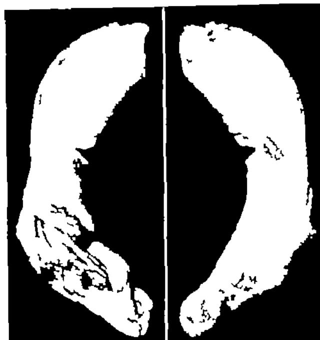


FIG 105 The inferior surface of the anterior segment shows numerous incomplete longitudinal tears there is also an incomplete transverse tear of the con cave margin. In this instance the anterior horn was detached completely from its bony attachment. (*Left*, inferior sur face, *right* superior surface)

ess at its periphery such as cysts or ad hesions Surface tears of both the anterior and the posterior segments of the lateral meniscus are common concomitant lesions of cystic degeneration of the structure. An other factor which renders the anterior seg ment of the lateral fibrocartilage more susceptible to trauma than its medial coun terpart is its anatomic position, lying in a plane slightly posterior to that of the an terior segment The author has encountered two cases in which the anterior horn of the medial structure was torn completely from its capsular and tibial attachments and dis placed into the intercondylar notch. In one of these cases the fragmented anterior horn had become attached to the anterior cruci ate ligament. In another case the anterior segment exhibited evidence of repeated trap-



FIG 106 Both the anterior and the posterior segments exhibit evidence of repeated trappings. An incomplete oblique split is discernible in the inferior surface of the posterior segment.



Fig 107 Incomplete transverse tear of lateral meniscus. *Usually this lesion is encountered at the junction of the anterior and the medial thirds.* (*Left* superior surface *right* inferior surface)



Fig 108 Usual location of a tra verse tear in the medial fibrocartilag it occurs in its posterior third (*Le* superior surface *right* inferior surfac

pings the inferior surface showed numer *ous incomplete parallel longitudinal tears* This specimen was of further interest because the anterior segment was torn completely from the capsule and the coronary ligaments and a small incomplete transverse tear was demonstrable at the center of its concave border the superior surface *of the segment was uninjured (Fig 105)* Another medial fibrocartilage disclosed findings consistent with repeated injuries to both surfaces of the anterior and the posterior segments The anterior segment revealed numerous incomplete longitudinal tears of the superior surface with pro*nounced hypertrophy of the affected region* the inferior surface was severely macerated An *oblique incomplete split of the posterior* segment was discernible on its inferior surface (Fig 106) It becomes apparent that lesions of the anterior segments generally are produced either by a shearing force which tends to tear the anterior cornu from its anchorage or by a compression force (*with an added rotatory element*) which is responsible for the parallel longitudinal incomplete tears *It was recorded previously*

that, with the tibia fixed and the flexed if the femur is rotated internally medial meniscus is displaced backwar the medial femoral condyle hence the *terior segment may be pulled from* attachments or its attachments may *stretched sufficiently to allow inward* placement of the anterior segment suc extension of the joint at this point may the anterior segment between the artic surfaces of the femoral and the tibial dyles In this same mechanism the fem condyle sweeps the lateral meniscus *ward making marked traction on the* tachment of its anterior cornu This forc *greater by far than that made on the a* rior segment of the medial structure by medial condyle in a backward direct (Fig 88) External rotation of the fe reverses the above mechanism never less the traction force made by the exte condyle on the attachment of the ante *segment in a backward direction is gre*

than that made by the medial condyle on the medial anterior segment in an anterior direction. The factors responsible for the difference in the intensity of the traction forces are the wider arc that the lateral condyle makes in rotation, as compared with that of the medial and the posterior location of the anterior segment of the lateral meniscus in relation to the medial structure Both factors render the lateral anterior portion of the fibrocartilage more vulnerable to injury than the medial This affords an explanation for the higher incidence of lesions in the lateral structure



Fig 109 Observe that the margins of the transverse tear overlap, resembling the blades of scissors (*Left* superior surface, *right* inferior surface, lateral meniscus)

TRANSVERSE OR OBLIQUE TEARS

These lesions are most frequently encountered in the lateral meniscus, they may be incomplete or complete, the latter being extremely rare. In the lateral meniscus they are situated usually at the junction of the anterior and the middle thirds, while in the medial fibrocartilage they are situated in the posterior third (Figs 107 and 108) The latter must be distinguished from longitudinal tears of the posterior segment, in which *the distal end of the central segment* has been worn away and resembles a transverse tear, also they never are so extensive as those observed in the lateral fibrocartilage The mechanism producing the two lesions differs

As previously stated, forces which tend to spread the anterior and the posterior attachments of the menisci stretch the thin concave borders thereby producing a transverse tear Inasmuch as the lateral meniscus is a large segment of a small circle its concave margin is subjected to greater stresses than the medial meniscus which is a small segment of a large circle Usually the tear begins at the concave margin and curves gently backward and *toward the convex* border as far as the outer third of the breadth of the cartilage occasionally, it may traverse the peripheral third but only rarely does it divide the meniscus completely (Fig 107)

The frequent association of transverse tears with cystic degeneration of the lateral cartilage leads one to believe that a close relationship must exist between the two lesions It is reasonable to assume that cystic alterations at the periphery of the meniscus restrict its natural excursion, thereby predisposing it to injury Many of the old transverse tears exhibit a horizontal *division of the anterior margin into which* the posterior margin fits According to Smillie the horizontal cleavage may result from the hinge action of the meniscus at the site of the tear This motion forces the convex posterior margin to impinge against the concave anterior margin As the result of numerous repetitions of this motion, a horizontal split is formed in the anterior margin, the cleavage may traverse the entire breadth of the meniscus, so that the posterior margin of the tear may come to lie at the joint line, forming a distinct swelling in this region Occasionally the anterior and the posterior margins overlap and slide by one another without the formation of a *horizontal cleavage* in this they closely resemble blades of scissors (Fig 109) Transverse tears in the anterior aspect of the meniscus may be associated lesions of single or multiple longitudinal tears in the posterior segment (Fig 110)



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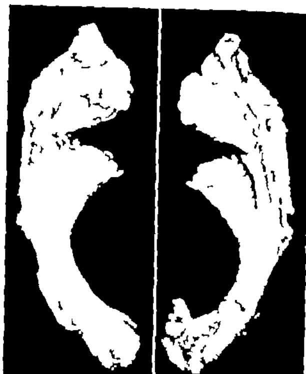


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pings, the inferior surface showed numerous incomplete parallel longitudinal tears This specimen was of further interest because the anterior segment was torn completely *from the capsule and the coronary* ligaments and a small incomplete transverse tear was demonstrable at the center of its concave border the superior surface of the segment was uninjured (Fig 105) Another *medial fibrocartilage* disclosed findings consistent with repeated injuries to both surfaces of the anterior and the posterior segments The anterior segment revealed numerous incomplete longitudinal tears of the superior surface with pronounced hypertrophy of the affected region the inferior surface was severely macerated *An oblique incomplete split of the posterior* segment was discernible on its inferior surface (Fig. 106) It becomes apparent that lesions of the anterior segments generally are produced either by a shearing force which tends to tear the anterior cornu from its anchorage or by a compression force (with an added rotatory element) which is *responsible for the parallel longitudinal in* complete tears It was recorded previously *that* with the tibia fixed and the knee flexed if the femur is rotated internally the medial meniscus is displaced backward by the medial *femoral condyle hence the an*terior segment may be pulled from its attachments or its *attachments may* be stretched sufficiently to allow inward displacement of the anterior segment sudden extension *of the joint at this point may trap* the anterior segment between the articular surfaces of the femoral and the tibial condyles. In this same mechanism, the femoral condyle sweeps the lateral meniscus forward *making marked traction* on the attachment of its anterior cornu This force is greater by far than that made on the anterior *segment of the medial structure by the* medial condyle in a backward direction (Fig 88) External rotation of the femur reverses the above mechanism nevertheless the traction force made by the external *condyle on the* attachment of the anterior segment in a backward direction is greater

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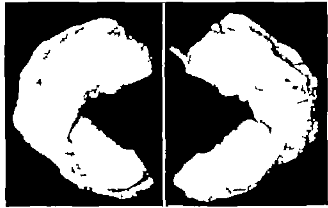


Fig 109 Observe that the margins of the transverse tear overlap resembling the blades of scissors. (*Left* superior surface *right*, inferior surface, lateral meniscus)

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Fig 110. Transverse tear associated with a longitudinal split through the peripheral portion of the posterior segment (*Left* superior surface *right* inferior surface lateral meniscus)



Fig 111 Small transverse tear on concave margins associated with a long complete tear in the peripheral region of both segments. The peripheral segment was displaced over the margin of the tibia. (*Left* inferior surface *right* superior surface medial meniscus)

COMBINED LESIONS

After the initial lesion has occurred the meniscus becomes vulnerable to repeated injuries The accumulative effects of these subsequent injuries may produce a great variety of lesions in the same meniscus (Fig. 111) Severance of the central portion of a longitudinal tear gives rise to tongue-like projections on the concave border they may be based anteriorly or posteriorly The tabs may become rounded and hypertrophied they may be detached completely from the main fragment as free loose bodies.

The clinical features vary with the size and the location of the processes Small tags located near the anterior or the posterior segment may produce vague signs of internal derangement, the principal features being giving way of the knee joint and a feeling of instability Large hypertrophied tags capable of being displaced into the anterior part of the joint anterior to the tibial collateral ligament may act as a mechanical wedge between the articular surfaces blocking full extension the same is true of loose bodies of fibrocartilage It becomes apparent that the clinical picture in the same individual may change from time to time depending upon the type of lesion or the combination of lesions present in the affected meniscus Transverse and longitudinal tears may exist in different portions of the same meniscus. Figure 111 exhibits a small transverse tear of the concave margin and a long longitudinal tear implicating the medial meniscus close to its convex periphery except at the extreme ends Figure 110 reveals similar lesions in a lateral meniscus

CYSTS OF THE MENISCI

General Considerations. The first comprehensive description of cysts of the meniscus was made by Ebner in 1904 This report stimulated interest in cystic lesions about the knee joint and in the subsequent years was followed by numerous articles dealing with this subject Smillie recorded the largest series of cases he encountered 146 cases in 1,500 meniscectomies In this group (1,500 cases) there were 966 medial menisci of which 20 exhibited evidence of cystic alterations (2%) 534 lateral fibrocartilages of which 116 showed degenerative lesions (22%) and 10 discoid cartilages with

cystic changes Analysis of the many reports in the literature and of the author's cases (48 cases) reveals that cystic abnormalities of the menisci is a disorder encountered most frequently in young athletic males In the author's group the age ranged from 17 to 58, the average being 26 5 there were 34 males and 14 females The lateral meniscus was implicated in 40 cases (84%) and the medial in 8 (16%) (Table 4)

Etiology Although cystic changes in menisci are an accepted clinical entity, the etiology is still a controversial subject. Ebner expressed the opinion that the lesions are the result of cystic degeneration of the fibrocartilage associated with trauma This view has been challenged by several workers nevertheless the accumulative evidence indicates that trauma is the causative agent responsible for the characteristic cystic alterations in the fibrocartilages The following are some of the theories concerning the formation of cysts of the menisci which have been advanced by different investigators Ollerenshaw proposed that the cysts are derived from embryonic rests of synovial cells within the meniscus and that trauma stimulates these cells to secrete fluid and produce distention cysts Geschickter and Lewis put forward evidence that the disorder was produced by synovial inclusions which are closely related to cysts arising in synovial membrane and to ganglia developing in tendon sheaths Zadek and Jaffe expressed the belief that the cysts developed from synovial tissue implanted into cartilage at the time of trauma King suggested that the cysts were the result of the activity of cells secreting gelatinous fluid Ledderhose attempted to show that obliterative changes in the arterioles of the parameniscal tissue was the responsible factor

In support of the traumatic theory, several significant observations must be recorded The incidence of a definite history of direct trauma to the knee or of a rotatory strain is noted in a large percentage of the cases. In the author's series a specific his-



FIG 112 Incomplete transverse tear of the lateral meniscus complicated by the presence of cystic degeneration

tory of injury was observed in 48 per cent of the cases, the trauma was a direct blow in 26 per cent and a twist or a rotatory strain of the knee in 22 per cent In the remaining cases a history of a specific injury was not obtainable however, it is conceivable that some form of minor trauma which escaped notice of the patient did antedate the formation of the cyst, particularly when one notes that the lesions are generally encountered in individuals engaged in strenuous forms of athletics or work The lateral meniscus is more vulnerable to direct trauma than the medial, in addition, the lesions are invariably located in the middle third of the lateral fibrocartilage This is the only portion of the meniscus exposed to direct injuries the anterior and the posterior thirds project inward under cover of the ligamentum patellae and the fibular collateral ligament It was interesting to note that the medial meniscus was implicated in 8 of the 48 cases in the writer's series in all 8 a history of direct injury to the anteromedial aspect of the knee was obtainable. The outer convex periphery of the lateral structure is thicker than that of the medial and



FIG 113 Cystic degeneration of a lateral meniscus associated with two longitudinal tears of its posterior segment. (*Left*) The cystic region has been divided longitudinally Observe the numerous rounded cysts of varying size most of which occupy a parameniscal position



FIG 114 Cystic degeneration implicating the anterior horn of the medial meniscus. The small figures (*right*) show the multiple cysts in a portion of the involved area which was sectioned longitudinally

is more susceptible to compression by forces tending to abduct the lower leg on the femur Rotatory strains produce lesions of the entire lateral meniscus close to its convex periphery whereas the same mechanism results in tears of the more central portions of the medial fibrocartilage the greater freedom of movement in the lateral structures is responsible for the frequency of the lesions close to its periphery Not infrequently tears of the meniscus are concomitant lesions of cystic degeneration oblique or incomplete tears are the lesions most commonly encountered (Fig 112) In one lateral meniscus the condition was associated with a complete longitudinal tear of the posterior segment (Fig 113) It is logical to assume that cystic degeneration binds the meniscus to the capsular structures thereby restricting its natural range of movement and rendering it more vulnerable to trappings on the other hand both lesions may be the result of a single injury Figure 114 depicts cystic degeneration arising from the anterior horn of the medial meniscus The patient a male 19 years old was kicked on the anteromedial aspect of the knee when participating in a game of football Several hours after the incident the anterior region of the knee became swollen painful and discolored He was treated by rest and ice packs to the injured part After 7 days the patient resumed his football activities and finished the season Approximately 4 months after the injury he noticed a small lump" at the joint line on the inner side of the ligamentum patellae He was aware of a clicking sensation on walking and with activity the knee became painful Exploration of the knee joint revealed a well formed cystic mass attached

to the periphery of the anterior segment of the medial fibrocartilage This case provides evidence that trauma to the medial meniscus is capable of producing cystic degeneration at the site of injury, and the lesions are comparable in every respect with those encountered in the lateral structure Also cystic alterations are observed in those regions of both menisci which frequently exhibit evidence of recent or old injuries particularly at the peripheral attachments of their anterior and posterior horns

The true nature of the cells lining the cysts has been the basis of much of the disagreement on the causation of the disorder However the weight of evidence, mostly determined by microscopic study is in favor of the theory that the lining cells are compressed proliferating fibroblasts and are not of endothelial origin The condition must not be confused with the parameniscal cysts arising from bursae and synovial out pouchings from the joint such as described by Bennett and Shae these cysts are lined by endothelium The author has reported previously 6 cases of cysts arising from bursae beneath the fibular collateral ligament in one of the cases the lesion was associated with a discoid cartilage Microscopic examination revealed no involvement of the discoid structure.



Fig 115 Large area of cystic degeneration implicating the middle third of the lateral meniscus. The entire thickness of the meniscus is implicated the affected area is expanded at the center and tapers anteriorly and posteriorly (*Left* superior surface *right* view of convex surface)

Pathogenesis The pathogenesis of the condition is not definitely established Some workers are of the opinion that trauma is followed by hemorrhage into the affected region of the meniscus next, mucoid degeneration of the hematoma occurs and this is followed by the formation of a cyst wall by compression of the surrounding fibrocartilage It is generally accepted that the essential feature in the development of the lesion is mucoid degeneration of the fibrocartilage In the first phase of the process the fibrils of the cartilage become swollen and less distinct and concurrently the cartilage cells show evidence of disintegration Minute cysts now make their appearance surrounded by a zone of proliferating round and spindle cells the process indicates an attempt toward repair by nature With increase in the size of the cysts the fibroblasts are compressed to form a limiting wall consistent with a lining membrane It is doubtful that obliteration of vessels in the region of the peripheral attachment of the affected portion of the fibrocartilage plays a role in the causation of the degenerative process because the peripheral regions are amply supplied with blood vessels, particularly in young people It is more reasonable to assume that the rising tension in the fluid in the primary cysts resulting from the initial degenerative process makes undue pressure on the surrounding fibrocartilage, which in turn undergoes degeneration It becomes apparent that two processes progress concur



FIG. 116 Lateral meniscus with extensive cystic degeneration. The lesion was visible and palpable anterior to and beneath the fibular collateral ligament (Fig 117) (*Right*) The lesion sectioned longitudinally Observe the presence of large cystic areas.

rently one characterized by cystic degeneration of the meniscus and the other by repair through fibrosis Eventually, the large cysts are extruded from the meniscus and may penetrate through the capsule to occupy a parameniscal position (Fig 113)

Macroscopic Features. The gross appearance of the cystic lesion depends upon its size location duration and the presence or the absence of recent injury As noted previously, in the lateral meniscus the disorder generally is situated in its middle third (Fig 115) Some lesions arising from the extreme periphery of the fibrocartilage grow to an appreciable size They may come to lie in the interval between the meniscus and the tendon of the popliteus muscle if growth continues the portions anterior and posterior to the popliteus tendon rupture through the capsule to occupy a position immediately under the deep fascia of the leg Frequently, the anterior portion of the cystic mass can be seen and palpated beneath and anterior to the fibular collateral ligament (Figs. 116, 117) Other lesions tend to extend centrally involving the breadth and the thickness of the meniscus so that the affected segment is expanded markedly at its center and tapers anteriorly and posteriorly (Fig 115) Such lesions are fixed to the capsule but do not penetrate it in other words, they do not occupy a parameniscal position Cysts of this nature may produce pressure on the synovial membrane

FIG 117 (A, *Left*) Lesion shown in Figure 116 It produced a firm rounded swelling anterior to and beneath the fibular collateral ligament Knee extended. (B *Right*) Lesion shown in Figure 116 Knee flexed.





of the femoral condyle and the articular borders *of the femur and the tibia in con* tact with the affected meniscus This irrita tion may be responsible for osseous and cartilaginous alterations which resemble those of hypertrophic arthritis.

Lesions of the medial meniscus are en countered more frequently in the region of the peripheral attachment of the anterior and the posterior segments (Fig 118) Like the cysts of the lateral meniscus, they tend to rupture through the capsule and occa *sionally through the fibers of the tibial col* lateral ligament Also, they usually attain larger proportions than the lesions of the lateral meniscus As a rule, the lesions arise from the peripheral zone of the fibrocarti lage and later occupy a parameniscal posi tion on rare occasions they invade the greater portion of the fibrocartilage and retain an intracapsular position

The outer aspect of the cystic mass may exhibit domelike projections which are really clusters of smaller cysts, *these often* are limited by a glistening membrane and may be discolored by fresh or old hemor rhages within the cyst cavities In addition, *the outer surface of the lesions* beyond the periphery may be irregular and exhibit evi dence of fibrosis and adhesions. The affected segment of the meniscus appears swollen and on section one notes that the entire mass is honeycombed by cysts varying in size and filled with a soft yellow gelati nous material (Figs. 113, 114) the indi vidual cysts range in size from lesions barely perceptible to the naked eye to cysts measuring 3 to 4 cm in diameter The fibro-cartilage between *the cysts is* softened, ede-matous and exhibits evidence of degenera tion. The entire mass is multilocular the loculi being separated by fine septa of fibrous tissue. The smaller cysts are found in the substance of the fibrocartilage while the larger ones tend to extend toward the periphery and eventually assume para meniscal positions

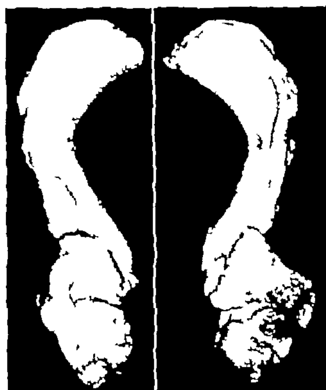


Fig 118 A large cystic mass arising from the anterior cornu of a medial meniscus. It lay immediately beneath the fascia of the leg and was palpable *at the joint line on the inner aspect of* the patellar tendon. (*Left*, superior sur face, *right*, inferior surface)

Microscopic Features. Microscopically cysts in varying stages of development are discernible The earliest alterations are manifested by myxomatous softening areas of the cartilage The fibrils become swollen and indistinct, they lose the normal pattern of arrangement and stain poorly, and the cartilage cells show evidence of disintegra tion *Further progression of the process* re veals the appearance of small clefts or slits in the degenerated cartilage these enlarge to varying size and represent the cysts ob-served macroscopically Some of the large cysts are semilocular others are divided by fine septa into multilocular cysts (Fig 119) Throughout the affected portion of the fibrocartilage and surrounding the degen erated areas described above, a highly vas-cular connective tissue is discernible it comprises round cells, spindle cells and blood vessels This tissue appears to arise in the vascular zone of the meniscus and



FIG 119 Photomicrograph × 50 of an area of cystic degeneration in a lateral meniscus Observe the formation and coalescence of small clefts in the degenerated fibrocartilage to form larger multilocular cysts. Also note the highly vascular connective tissue creeping between the degenerated areas.

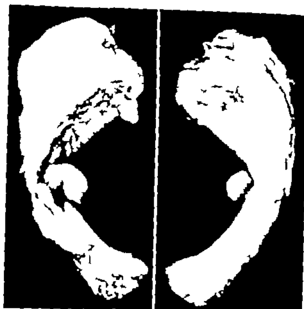


FIG 120 Discoid medial meniscus approaching the infantile type Note the pedunculated tag resulting from a transverse tear superimposed on the central portion of a longitudinal tear (*Left* inferior surface *right* superior surface)

creeps between the degenerated areas With enlargement of the cysts this tissue is compressed and eventually becomes the limiting wall or a lining membrane of the cyst In some areas fibrosis is a prominent feature Areas of hyalinization and thickening of the walls of the blood vessels are demonstrable some vessels appear to be partially occluded The flattened connective tissue cells which line the cysts must be distinguished from the endothelial cells which line parameniscal cysts arising from bursae and synovial outpourings of the capsule

Old lesions exhibit extensive fibrosis and evidence of chronic inflammatory changes and old hemorrhages Freshly traumatized cysts may reveal evidence of recent hemorrhage

LESIONS OF DISCOID MENISCI

General Considerations. The anatomy and the varieties of congenital discoid menisci were discussed in Chapter 3 Although the structures are rarely encountered they are vulnerable to injury and exhibit characteristic lesions In the writer s series there were 18 discoid menisci of these 17 were observed in the lateral compartment of the knee joint and 1 in the medial There were 11 males and 7 females the right knee was implicated in 10 cases and the left in 8 The age ranged from 6 to 43 there was 1 bilateral case No case was encountered which had both lateral and medial discoid menisci The rarity of medial discoid cartilages is evidenced by the paucity of recorded cases in the literature The first case was reported in 1945 by Dwyer and Taylor although Smillie encountered a case with cystic degeneration at its periphery in 1943 Both these cases exhibited a horizontal cleavage The author s case revealed a longitudinal tear whose central portion had been severed transversely leaving a proximal and a distal pedunculated tag (Fig 120)

Type of Lesions The pertinent observation in all cases encountered was the hyper

mobility of the discoid structures as compared with the normal In addition, the actual bulk of tissue between the articular surfaces renders them vulnerable to compression and rotatory stresses It becomes apparent that the premature disk, which essentially is more or less a complete septum of fibrocartilage between the articular surfaces, is prone to show a combination of lesions produced by the aforementioned forces and will exhibit more extensive alterations than the other two types (the intermediate and the infantile types), which are less bulky and approach more closely the size and the configuration of the normal meniscus

Hypermobility of the Meniscus. Hypermobility may or may not be associated with other lesions of discoid menisci In this series 4 cases exhibited no detachment or other lesions, the structures appeared to be well anchored to the capsular and tibial attachments Two cases showed no gross lesions of the meniscus, but considerable amounts of forward and backward motion were demonstrable on extension and flexion of the knee Certainly this abnormal excursion of the structures increases their susceptibility to injury All structures showing lesions of their surfaces or substance also disclosed varying degrees of detachment of their anterior portion or an excessive range of backward and forward motion

Detachment. Hypermobility may be the precursor of detachment Middleton noted that when the knee is approaching full extension the femoral condyle slips over the anterior margin of the loose discoid fibrocartilage and forces it backward in the direction of the posterior compartment This explanation is particularly applicable

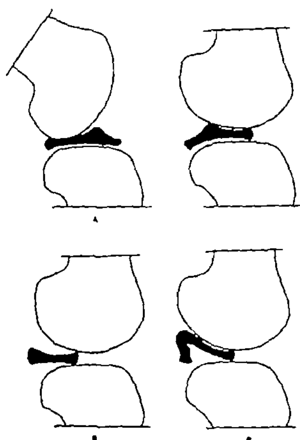


Fig 121 The cause of 'snapping" (A) Relation of femoral condyle to the ridge in flexion (B) Relation of femoral condyle in extension. (C) The condyle has slipped over the anterior compartment. (D) The condyle has slipped over the anterior margin of a large disk flexed upon itself in the posterior compartment. (From Smillie Injuries of the Knee Joint, Baltimore Williams & Wilkins)

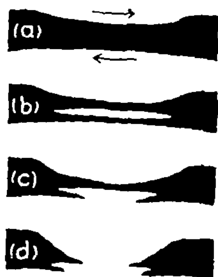


Fig 122 Diagrammatic representation of the stages of horizontal cleavage (A) The superior and the inferior surfaces shift in relation to one another (B) A line of cleavage appears. (C) The inferior surface wears away (D) Wearing of both surfaces results in a central hole. (From Smillie Injuries of the Knee Joint, Baltimore Williams & Wilkins)



FIG 123 Primitive discoid lateral meniscus. *Note that it is massive in size* comprising a complete disk with thick peripheral and central margins. The hollow in its superior surface to accommodate the femoral condyle is visible (*Left* inferior surface *right* superior surface)



FIG 124 Primitive discoid lateral meniscus with a central defect produced by *the wearing away of the superior and the* inferior surfaces. A horizontal plane of cleavage around the defect is also present Note that the central portion is thinner than the peripheral and the central margins. (*Left* superior surface *right* inferior surface)

to small primitive disks with loose peripheral attachments. In cases of large discoid menisci, the same mechanism may force the meniscus to buckle upon itself when it is driven into the posterior compartment Upon flexion of the knee the mechanism is reversed, and as the condyles slip behind the anterior edge of the meniscus the structure snaps into its natural position

The presence of ridges on the superior surface of the menisci, particularly those of the primitive type, has been the cause of considerable speculation According to *Smillie, the ridges are produced by the* wearing away of the inferior surface which allows the superior surface to descend to a lower level, thereby forming a shallow hollow to accommodate the femoral condyle The ridge may run transversely, obliquely or in an anteroposterior direction In the presence of a transverse ridge the femoral condyle rides over it when full extension is approached driving *the* structure backward the reverse is true when the knee is flexed (Fig 121) It becomes apparent that through repetition of the maneuver described above or as the result of abnormal forces of tension and compression the anterior ligaments and the capsular attach*ments become stretched attenuated and* finally torn, resulting in complete detachment This lesion was noted in two cases in one the entire meniscus was displaced into the posterior compartment of the joint and had become fixed to the capsular tissues in this region The second meniscus was displaced in the intercondylar space In all of the remaining menisci in this series, some degree of stretching and attenuation of the anteromedial attachment was demonstrable

Horizontal Tears. These lesions are encountered *most commonly* in the primitive type which is characterized by considerable thickness. The most plausible explanation of their mode of origin was conceived by Smillie the horizontal cleavage is the result of continuous movement of the superior surface on the inferior surface (Fig 122) This is possible because the superior surface is relatively free moving with the fem*oral condyle while the inferior* is fixed to the tibial plateau (Fig 123) Continuous flexion and extension plus rotatory stresses eventually cause a split between the two surfaces In one of the specimens in this series the horizontal lesion was not discernible until the disk was sectioned the line

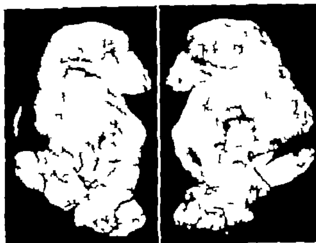


FIG 125 Intermediate discoid meniscus. Note that its bulk is less than that of the primitive type and that it exhibits 2 notches on its central margin. Several incomplete longitudinal tears are seen on the inferior surface (*Left* inferior surface *right*, superior surface)



FIG 126 Infantile discoid meniscus with an incomplete oblique tear (*Left* inferior surface, *right* superior surface)

of cleavage had no connection with the periphery In more advanced lesions the inferior and the superior surfaces are worn away gradually by the continuous forces of friction so that eventually an irregular circular defect is formed in the center of the disk (Fig 124) Generally the line of cleavage between the two surfaces is demonstrable at the margin of the defect on the inferior surface Horizontal lesions of varying severity were observed in 6 of the cases.

Longitudinal Tears. Incomplete longitudinal tears are relatively frequent at the peripheral attachments of the primitive discoid cartilage the intermediate type is even more likely to show complete as well as incomplete tears These usually are located in the posterior portion of the disk and represent incidences of repeated injury All 3 cases in this series exhibited complete posterior tears (Fig. 125) A longitudinal tear with a superimposed transverse tear of the central portion was observed in one medial discoid meniscus of this series the proximal pedunculated tab became displaced anteriorly and caused locking of the joint (Fig 120) This specimen also showed a long incomplete longitudinal tear of the inferior surface of its posterior convex border close to the peripheral attachment Longitudinal tears are found also in the infantile forms usually at the periphery or through the capsular attachments.

Transverse Tears Transverse or oblique tears are associated more commonly with the infantile disk than with the other two types (Fig 126) Inasmuch as this variety closely resembles the normal lateral meniscus, *it is logical to assume that it is sus-*



FIG 127 Infantile discoid meniscus showing an extensive longitudinal tear of the posterior segment. (*Left* superior surface, *right*, inferior surface)



FIG 128 Calcification of the lateral meniscus in a female 48 years old Cystic degeneration of the periphery of the meniscus was also present. Note the secondary bone reaction at the outer articular margins of the femoral and the tibial condyles.

ceptible to the same abnormal stresses as the normal lateral structure and hence should exhibit similar lesions Clinical observation substantiates this premise. In fact the short concave border of the wide infantile disk exhibits a higher incidence of transverse tears than the normal structure because it is less capable of counteracting those forces which tend to increase the interval between the anterior and the posterior cornus. Four of the 5 infantile disks in this series disclosed a transverse or an oblique tear the other revealed no gross abnormality (Fig 127)

Cystic Degeneration Many observers are noting the high frequency of cysts associated with discoid fibrocartilage In the author's series 4 of the 18 discoid menisci revealed cystic lesions 1 was observed in the primitive structures and 3 in the infantile menisci If one contends that trauma is a causative factor in the production of cysts then the high incidence noted in discoid menisci is readily explainable, because certainly these structures are more susceptible to abnormal compression and rotatory stresses than the normal menisci On the other hand, there is some evidence in support of the premise that cysts arise from embryonal cells within the substance of the fibrocartilage which are activated by trauma. The discoid menisci are more likely to harbor embryonal cells than the normal structure The argument set forth to discredit this theory is the absence of an endothelial lining in true cysts of the fibrocartilage. The writer is of the opinion that trauma is the etiologic agent responsible for cystic degeneration of the menisci

CALCIFICATION IN MENISCI

This entity is relatively rare and may occur in the younger age group following injuries to the knee and in the older age periods as a concomitant feature of degenerative arthritis

Calcification in Menisci Associated with Trauma

This lesion usually implicates only one of the menisci and as a rule produces symptoms of internal derangement of the joint As noted above it generally occurs in young people engaged in strenuous sports A history of injury to the knee is always present Calcification may be associated with other lesions of the meniscus or it may exist as a single lesion The most pertinent feature of the disorder is the presence of a well delineated shadow of increased density in the medial and the posterior compartment of the joint If calcification of the meniscus is not suspected this may be interpreted erroneously as a loose body If the disorder



Fig 129 Primary calcification of both menisci Note the linear areas of calcification arranged parallel to one another



Fig 130 Complete ossification of the lateral meniscus following depressed fracture of the lateral femoral condyle. Note the loose body in the intercondylar notch.

is associated with tears of the meniscus, true locking of the joint may ensue however, the usually important clinical features are giving way of the joint, often associated with a click' pain and varying degrees of swelling Correct interpretation of the clinical and the roentgenographic features preclude unnecessary surgery in search of a loose body Excision of the affected meniscus invariably cures the disorder

The writer has encountered extensive calcification in a lateral meniscus which disclosed cystic degeneration of its periphery the patient was a female 48 years old The cysts formed a distinct mass under and anterior to the fibular collateral ligament It was interesting to note the secondary bone reaction at the outer articular margins of the femoral and the tibial condyles In this region irregular bone formation closely resembling that observed in hypertrophic arthritis was demonstrable (Fig 128)

Calcification Associated with Degenerative Joint Changes

On occasion calcification in the menisci is observed in knee joints exhibiting other manifestations of degenerative changes consistent with hypertrophic arthritis Generally both fibrocartilages are involved The roentgenographic features of the lesion are distinctive in the joint space one notes linear areas of calcification arranged parallel to one another (Fig 129) The calcareous deposits vary in density some exhibit an amorphous character while others are more dense and discrete

In degenerative processes the next step following calcification in tissues is ossification such lesions have been observed in both the traumatic and the degenerative forms of calcification of the menisci Figure 130 depicts extensive ossification of the external fibrocartilage following a depressed fracture of the lateral tibial condyle Ossification is so complete that bone trabeculae arranged in the lines of stress and paralleling those of the femoral and the tibial condyles are demonstrable in the meniscus This patient presented symptoms of internal derangement which were relieved by the removal of the loose body found in the intercondylar notch the ossified meniscus was not disturbed (Fig 130)

REGENERATED MENISCI

Lesions of regenerated menisci following total excision of the normal structure are exceedingly rare lesions following partial extirpation (in which the posterior segment is left in situ) are relatively more common In this series of 507 meniscectomies 13 regenerated menisci were encountered In 10 the original posterior segment was still demonstrable, in the remaining 3, total regeneration had occurred In general the connective tissue replica is less vulnerable to injury than the normal structure The factors which mitigate the incidence of injury are the reductions in size and the diminished range of motion of the structure as compared with the normal The replica is firmly adherent to the capsule and its breadth and thickness are considerably less than the same dimensions of the original meniscus In the light of these observations it becomes apparent that the mechanisms which inflict injuries of the original fibrocartilage are less likely to produce lesions of the regenerated meniscus also when lesions occur they are of less severity than those which generally occur in the normal fibrocartilage The nature of the lesions is the same in both the normal and the regenerated menisci (Fig 87)

CLINICAL FEATURES—FACTORS PREDISPOSING MENISCI TO INJURY

Developmental Factors

The knee joint in man is a highly specialized and intricate organ which from a biologic viewpoint is of recent origin It has assumed the functions of weight bearing and equilibrium for which it was not designed primarily These factors play a major role in the high incidence of knee injuries certainly the rapidity with which the quadriceps muscle undergoes atrophy and loses volume in the face of even minor injuries to the knee joint is a good indication of the biologic newness of this organ as it exists in man It was pointed out previously that loss of quadriceps efficiency favors instability of the joint and formation of effusions these factors in turn predispose the menisci to abnormal stresses and injury

Anatomic Factors

The knee joint exhibits specific peculiarities which increase the susceptibility of the menisci to injury When compared with lower forms, one notes immediately the increase in the relative size of the femoral and the tibial condyles in man Also the configuration of the articular surfaces of the femoral condyles is such that the joint is locked in extension by the screw home maneuver previously described These alterations in the bony elements increase the vulnerability of the fibrocartilages which are comparatively delicate small structures between massive bone ends partaking in intricate movements during normal function of the articulation Such a delicate mechanism is deranged readily inflicting injury to the menisci

The stability afforded by the cruciate ligaments in the lower forms is lacking in man in the forms holding the knee habitually flexed these ligamentous structures are strong and well developed It was pointed out that in primates which use the lower limbs as prehensile organs and swing from branch to branch the cruciate ligaments are usually large and strong In man the ligaments are reduced greatly in size and do not provide the knee joint with the protection that they afford the knees of lower animals

On the other hand the fibrocartilages have attained their highest degree of development in man This has been necessary in order to meet the new functional demands made on the knee joint The increase in breadth and width which they have acquired and the freedom of motion they enjoy during flexion and extension of the joint are factors which render them vulnerable when abnormal stresses are applied to the knee

joint In addition, variations in size and shape are responsible for specific types of lesions, this has been amply demonstrated in lesions of the lateral and the congenital discoid cartilages

Constitutional and Occupational Factors

The high incidence of tears of the menisci in young people engaged in arduous sports is well recognized Nevertheless, there is a certain group of cases in which the lesions are the result of trivial injuries sustained in domestic life. Every orthopedic surgeon at some time or other must have observed that in many of the aforementioned cases a close relationship exists between the physical status of the patient and the resulting injury to the knee joint. An observation of significance is the marked laxity that is demonstrable in the quadriceps and the ligamentous apparatuses of some individuals Surely such persons must exhibit the same relaxation and laxity in the coronary ligaments thereby permitting the meniscus a greater excursion of motion than they normally have Overweight individuals with generalized poor muscle tone also are more susceptible than those of normal weight and good muscular development

American sports such as football, baseball and basketball are responsible for the largest percentage of lesions of the menisci in this country These sports and others are also accountable for the high incidence observed on the continent. Occupations which maintain the flexed lower leg in a fixed position and prevent normal rotation of the tibia on the femur during flexion and extension are common causes of internal derangements of the knee. Smillie points out that coal mining in England where the seams are narrow is also responsible for a large number of cases the miners are forced to work with the knees flexed During flexion and extension of the knee the tibia of the miner is unable to rotate on the femur in the proper direction because the inner and the outer borders of the feet are in contact with the floor It becomes apparent that in such circumstances undue strains are placed on the coronary ligaments during extension and flexion of the joint, these structures eventually become stretched and predispose the menisci to trappings between the condyles of the femur and the tibia. Besides sports and coal mining, numerous incidents may occur in a great many forms of occupation which provide the requisites responsible for internal derangement of the knee The author has observed a large number of cases in young men working on telephone and telegraph poles These individuals wear spiked shoes which fix the feet and the legs to the poles during the course of their work they are constantly leaning from one side to the other and twisting their trunks In so doing, the flexed knees are subjected to undue rotary strains which in many instances are of sufficient severity to cause tears of the menisci

Pathologic Factors

Any disorder which reduces the efficiency of the quadriceps as a stabilizer of the knee joint predisposes the patient to internal derangements of the knee Trivial injuries attended inadequately may result in profound quadriceps wasting which in turn is accompanied by recurrent effusions. Under such circumstances the entire ligamentous apparatus and the capsule become relaxed, this includes the coronary ligaments which anchore the menisci to the tibial tuberosities. The resulting increased mobility of the menisci, together with the loss of the protective nature of the quadriceps, favors trippings of the menisci these may occur in association with minor abnormal stresses which under normal conditions would not be capable of producing injuries of the fibrocartilages Any mechanical derangement of the knee may cause the same sequence of events noted above. Notably among these are genu valgum which imposes undue strain on the internal ligaments

of the knee a poorly developed lateral condyle of the femur which permits recurrent subluxations or dislocations of the patella and an abnormally elongated patellar tendon with congenital relaxation of the ligaments and the capsule which also is responsible for lateral displacement of the patella It is obvious that any agent causing loss of muscle tone and recurrent synovial effusions increases the vulnerability of the menisci

Age, Incidence and Sex Factors

Critical analysis of the numerous series of lesions of the menisci reveals that the lesions occur most frequently in the third decade of life, this was true in the author's cases The next period in order of frequency was the fourth decade It is interesting to note the high incidence occurring in the young adult males as compared with the females In the series reported herein there were 465 males (91.8%) and 42 females (8.2%) This ratio certainly points to the important role that trauma plays in the production of lesions of the menisci

Diagnostic Factors

In certain instances the diagnosis of a torn meniscus or another form of internal derangement of the knee joint is established without difficulty this is especially true when a patient presents himself with a locked knee joint and gives a history of a twisting injury to the limb On the other hand the diagnosis may challenge the most keen diagnostician particularly old cases of internal derangement which are seen between attacks of recurrent injury When present certain symptoms signs and physical findings provide sufficient data to make a diagnosis in most instances however in their absence the surgeon must depend heavily on the details of the history to arrive at any conclusions On occasion the diagnosis can be established only by exploration of the knee joint The diagnostic acumen of the surgeon can be enhanced greatly by analyzing meticulously all the details of the whole clinical picture This can be achieved only by taking the history of the patient and performing the examination with a definite preconceived plan all data should be recorded The plan should include a description of the operative findings and a correlation of these observations with the history and the preoperative examination of the patient The author has found the following plan to be adequate

Scheme of History Taking and Physical Examination

Name
Knee affected
Age Sex Color
Occupation
HISTORY
Date of initial injury
Mechanism of initial injury (as described by the patient)
Symptoms associated with initial injury
1 Pain—location
2 Presence or absence of click or snap at time of injury
3 Swelling—location and time of appearance after injury
4 Degree of dysfunction immediately after injury
5 Locking—present or absent after injury
6 Tenderness—location
Immediate management after initial injury
Nature of symptoms after initial injury
Present complaints—swelling instability locking pain etc.
Physical examination of affected knee
1 Position of the extremity—extended or flexed
2 Effusion—present or absent
3 Loss of muscle volume—degree (mild moderate severe)
4 Measurements of circumference of thighs (taken at points measured from the anterior superior spines)
5 Range of free motion—active and passive
6 Crepitus associated with motion—presence or absence of click and location
7 Tenderness—location
8 Lateral instability
9 Anteroposterior instability
10 Presence or absence of undue laxity of capsule and quadriceps apparatus

11 Presence or absence of crepitus in patellofemoral joint
12 Tests
McMurray
Fouche
Roentgenographic study
Presumptive diagnosis
Operative findings
Final diagnosis

History Factors

As previously recorded, in many instances meticulous interrogation of the history of the case is more important than the physical examination Little or no information may be available by examination of a knee after an acute episode has subsided, yet the history may provide valuable data leading to the correct diagnosis of the disorder Much can be learned if the patient is allowed to tell the story in his own words and is asked to demonstrate the position of the limb after the injury and to point out the areas of maximum pain and tenderness

It is important to ascertain whether or not some form of disorder existed in the knee prior to the initial injury or to the symptoms which force the patient to seek medical aid Not infrequently the severity of the existing symptoms or the apprehension of the patient relegate symptoms of lesser severity to the background so that it requires painstaking questioning to establish their presence Such information as recurrent effusions giving way of the knee joint and a sense of instability or "something jumping out of place" is valuable in determining the presence of predisposing factors—pathologic or anatomic—which eventually precipitate the major injury

It is surprising to observe how many patients, even very intelligent ones are not capable of giving a reliable description of the mechanism responsible for the internal derangement However the significant point to establish is whether or not a rotatory force was acting while the knee was in a position of flexion these requisites are essential to sustain tears of the menisci

CLINICAL FEATURES—SYMPTOMS

Pain

At the occurrence of the initial lesion of major tears, pain may be unusually severe, it is more or less generalized but more intense over the affected side The pain may be accompanied by a snap or a click which is felt and occasionally heard usually this indicates tearing of a meniscus or rupture of a ligament The pain is the result of severe stretching and tearing of the synovial and the capsular attachments of the affected meniscus, it is not caused by tearing of the substance of the fibrocartilage. In some cases major tears of the meniscus with or without locking occur after numerous minor incidences associated with moderate pain and effusions Eventually a major tear ensues however, the intensity of the pain as a rule, is not equal to that observed in cases with a severe initial lesion without previous symptoms On occasion a case is encountered in which a trivial injury results in a major initial tear of the meniscus yet the patient gives no history of previous symptoms In such cases the intensity of the symptoms may be mild or moderate in nature. It must be assumed that gradual stretching of the coronary ligaments, the capsule and the capsular attachments of the menisci has occurred in these cases thereby predisposing the menisci to severe lesions by minor injuries. It is interesting to note that the severity of the lesions of the meniscus sustained by the first injury is not commensurate with the intensity of the symptoms As has been recorded by other observers the author has encountered some of the most extensive tears in patients whose symptoms were initiated by a gradual onset, and at no time did they exhibit severe reactions In most cases the patient indicates correctly the site of the pain As noted above in recent injuries the pain may be generalized but is more pronounced on the affected side, in cases of long standing the

pain is more localized, and the patient invariably (except in very rare instances) *points to the painful area without hesitation* Occasionally, a unilateral lesion may cause bilateral pain, and a bilateral lesion may be associated with unilateral pain as a rule, the preponderance of tenderness over the affected meniscus establishes the site of the lesion In the author s series there were 16 bilateral lesions Of these 9 had pain and *marked tenderness on the medial side of the* joint lesions of the lateral meniscus were not suspected before operation Contralateral pain is not a reliable diagnostic sign often it may be caused by strains of the opposite collateral ligament

Click or Snap

This is a relatively common symptom and in original injuries is accompanied by excruciating pain Occasionally the click is heard by other people near the patient. In some old recurrent cases the patient may produce the click *voluntarily by flexing and extending* the knee joint In these cases the patient may have some discomfort but no pain

Effusion

Synovial effusion invariably accompanies every original tear of the menisci As pointed out previously it is the result of stretching and tearing of the *synovial* the capsular and the ligamentous attachments of the meniscus and is not caused by tearing of the substance of the fibrocartilage It becomes manifest within a few hours after the injury generally the maximum swelling is attained within 12 to 24 hours This point is characteristic of traumatic synovial effu*sion and must be distinguished from hemar*throsis in which there is a rapid distention of the joint

Traumatic synovial *effusion* is a concomitant finding of many other forms of injuries to the knee joint and its presence following injury does not necessarily indicate a tear of the meniscus Also with subsequent trappings of the meniscus regardless of whether locking does or does not occur varying amounts of effusion are always associated with the incident. Generally, the reactions are of lesser severity than the one which followed the original incident On rare occasions of long standing giving way or lock*ing of the joint may occur without reactions.* Large effusions do not give rise to acute pain but rather produce a feeling of tightness *and discomfort* in the knee joint This is in contradistinction to hemarthrosis which causes intense pain

Locking

True locking of the knee joint means that there is present a definite mechanical block to complete extension it occurs at a point *from 10° to 30° below complete extension* As previously noted it usually takes place when a longitudinal tear extends into the *anterior segment to a point* anterior to the collateral ligament In a few cases definite mechanical obstruction to extension is caused by lesions other than a longitudinal tear of the posterior segment extending anterior to the coronal plane of the joint Posterior or anterior peripheral tears which will permit the meniscus to be displaced into the center of the joint may produce classical locking the author has encountered two of the former and one of the latter *Also large tags based anteriorly or posteriorly* which come to lie in front of the femoral condyle may produce true locking Of particular interest was one case of a young man whose knee locked when he made a sudden turn pivoting on one leg while playing basketball He experienced excruciating pain and was forced to leave the floor When examined several hours later the knee was slightly swollen and locked at 165° A diagnosis of a torn *meniscus* was made and operation was recommended Upon exploration of the joint a large discrete pedunculated fatty tumor with its base *attached to the medial semi*lunar fat pad was found It was crushed

and wedged between the articular surfaces of the femoral and the tibial condyles The menisci disclosed no evidence of injury

It is generally recognized that it is difficult to ascertain a true incidence of locking at the original injury, also it appears that the incidence is lower than generally realized A survey of some of the series reported in the literature indicates that less than 50 per cent of the patients with lesions of the menisci gave a history of locking at some time during the course of the disorder and that in less than 50 per cent of these, locking occurred at the original incident In the remaining patients (over 50%) no history of locking was attainable The author's series portrays a picture similar to this Of 358 cases reviewed a history of definite locking at the original incident was obtained in 19 per cent, subsequent locking occurred in 26 per cent. In 55 per cent locking did not occur Several factors are responsible for the low incidence of locking at the initial injury Most important is the location and the size of the original tear in the meniscus It usually involves the posterior segment, hence, the lesion is not capable of obstructing the femoral condyle during extension of the knee In most instances in which the original tear extends anteriorly beyond the collateral ligaments, locking does not take place because spontaneous recoil of the central fragment forces the torn structure in its normal anatomic position in relation to the femoral and the tibial condyles The inherent elastic qualities of normal fibrocartilage such as is found in the menisci of young adults together with the shape of the menisci account for the tendency toward spontaneous replacement of the central fragment of a longitudinal tear

No one can deny that in the face of true locking together with a history pointing to the menisci as possible sources of trouble, a torn fibrocartilage is the most logical diagnosis. Under such circumstances locking may be considered as a characteristic feature of a torn cartilage However, more important is the ability to make a clinical diagnosis of a torn meniscus in the absence of locking because, as previously noted, in more than 50 per cent of the cases locking of the joint does not occur To confuse the clinical picture further, occasionally one encounters a complete longitudinal tear extending into the anterior segment of the meniscus with no evidence of locking, these patients complain of vague symptoms suggesting some form of internal derangement but exhibit no impediment to flexion or extension of the knee.

Many forms of pseudolockings may be interpreted erroneously as true lockings of the knee joint When true locking occurs, it is sudden and dramatic, even more characteristic of the lesion is the suddenness with which it may unlock, giving the patient a relatively free range of painless motion One must view with suspicion cases which are featured by inability to extend the knee but in which, during an interval of several days extension gradually returns to normal Most of these cases are instances in which a large effusion or severe muscle spasm are responsible for the restricted arc of extension, in some instances crushing of the infrapatellar fat pad, followed by enduration of the tissue effusion and hemorrhage may produce the same clinical picture. Hemarthroses resulting from ruptures of the collateral ligaments, tearing of the synovial and the capsular attachments of the menisci or fractures of the tibial spine may cause marked restriction of extension and may simulate true locking On the other hand, a massive effusion may mask a truly locked knee joint the actual nature of the lesion may not become manifest until the effusion has subsided and full extension fails to return If the surgeon is cognizant of these numerous pitfalls and carefully analyzes all the details of the history of the injury and carefully examines the part, as a rule he can make the correct interpretation of the condition at hand

Tenderness

In recent injuries some tenderness is demonstrable along *the entire periphery of the* affected cartilage however, it will be noted that in lesions of the internal meniscus it is *most acute at the joint line over, in front* of or behind the tibial collateral ligament This is a constant finding and must be distinguished from localized tenderness in conjunction with severe sprains of the collateral ligament. In such cases the maximum degree of tenderness is elicited at the superior or the inferior bony insertion of the ligament particularly in the region of the medial femoral epicondyle Even in recurrent cases tenderness over the aforementioned site is invariably present

Tenderness over the posterior segment immediately behind the posterior borders of *the collateral ligaments can be demonstrated* in recent tears of the posterior segment this finding is in addition to the tenderness noted *in the region of the tibial collateral ligament* in cases of lesions of the internal meniscus The stretching and the tearing of the peripheral attachments which is associated invariably with longitudinal tears of the posterior segment is responsible for the tenderness in this region In fact in recurrent cases this may be the only objective finding that is demonstrable

Tenderness localized over the anterior peripheral attachments of the menisci is present when these regions are implicated In lesions of the medial meniscus it can be demonstrated best by making firm pressure *with the thumb over the joint line in the* anteromedial angle of the joint while the knee is flexed The knee is then extended and as the leg approaches complete extension pain is elicited because at this point the convex surface of the meniscus is forced against the finger On the lateral side the same maneuver is executed with the finger placed about 2 cm from the lateral border of the ligamentum patellae Tenderness over the anterior peripheral attachments is not a reliable sign because it is a concomitant finding of many minor injuries not implicating the menisci

DYSFUNCTION IMMEDIATELY AFTER INJURY

The degree of dysfunction following the original injury is governed in a large measure *by the severity of the tear If the tear* implicates the fibrocartilage to the extent that locking ensues the resulting dysfunc*tion is marked*—so much so that the patient is unable to complete the task in which he was engaged This is also true of incidents in which the locking was reduced spontaneously or manually immediately after it occurred On the other hand momentary trappings of the meniscus producing complete or incomplete tears without true locking of the joint may produce only minimal dysfunction in fact if it occurs on the football field the player may continue with the game. Subsequent injuries may result in true locking which will totally incapacitate the patient The author has encountered a number of cases of original injuries on the football field in which it was apparent that the players had inflicted some injury to the *posterior segment of the meniscus* however the lesions were short of the extent of the split in the meniscus required to produce *locking In some of these players the knees* eventually locked following subsequent injuries

Physical Examination

Certain points in the examination of the patient need *elaboration*

POSITION OF THE EXTREMITY

When true locking occurs either at the original injury or at subsequent injuries the knee is flexed from 10 to 30 below the line of complete extension A player being carried off the football field assumes a characteristic attitude the knee and the hip are flexed the toe of the affected limb points downward and no weight is put on the limb It was pointed out previously that pain and

muscle spasm resulting from injuries other than a torn meniscus will restrict the arc of extension The author has observed numerous patients with supposedly locked knee joints in whom the joint would go readily into complete extension when muscle relaxation was obtained by general anesthesia. Massive synovial effusions and hemarthroses also may impede full extension

TESTING FOR EFFUSION

Joints distended with synovial effusion are ballooned out, forming a semicircular convexity around the lateral margins and the base of the patella Thus the mobility of the patella is increased, and ballotment of this bone is readily demonstrable by tapping its anterior surface gently In massive effusions fluctuation is readily discernible however smaller effusions are not detected so readily The method depicted in Figure 131 is of value in determining the presence of small effusions The examiner s hands are placed on the anterior surface of the limb above and below the patella gentle and uniform pressure is made above and below toward the center of the patella By so doing fluid in the joint, particularly in the suprapatellar pouch is displaced under the inferior surface of the patella. Then by gently tapping the patella with the index finger the bone can be felt to strike against the anterior surface of the femur the contact can be both felt and heard.

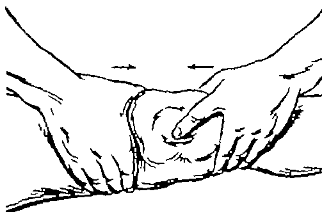


FIG 131 Method eliciting the presence of effusion

LOSS OF TONE AND MUSCLE VOLUME

Loss of tone and volume of the quadriceps muscle in varying degrees is a constant finding in all disorders of the knee joint The component showing the earliest and most profound alterations is the vastus medialis Even before there is visible loss of muscle volume careful and gentle palpation of the quadriceps will disclose loss of firmness and tone as compared with the unaffected side also careful inspection reveals a barely perceptible degree of flatness which is rarely missed once the examiner learns to detect it It is a good policy to measure the circumference of both thighs at about their mid points The author employs the tips of the anterior superior spines of the iliac crest as the fixed points In addition, measurements may also be taken at the level of the supra patellar region, the joint line and the mid calf It is important to emphasize that mensuration of the two thighs at the same respective levels is not a true index of the presence or the absence of wasting of the quadriceps Often the readings are identical yet the trained observer can detect and feel a difference in the firmness and the tone of the two muscle masses Only in rare instances does one encounter a meniscal lesion without some degree of wasting of the quadriceps, in such instances the nature of the lesion is such that the function of the joint is not impaired and in addition the activity of the extremity has been maintained at a high level, such as is observed in athletes in constant training

BUCKLING OR GIVING-WAY

Giving way of the knee joint is the most frequently encountered symptom of internal derangement in which the menisci are at fault yet it is commonly overlooked as a diagnostic sign of such lesions The patient's description of the incident may be vague and confusing nevertheless, a few leading questions will reveal the true nature of the pathology responsible for the disorder The patient may describe the symptom as ' some

thing slipping out of place" or the "joint jumping out" Invariably he develops a sense of instability in the affected extremity and soon learns that certain acts will predispose the knee to giving way such as walking on uneven terrain or pivoting on the affected leg Numerous causes may produce giving way incidents such as atrophy of the quadriceps muscle anterop instability resulting from stretching of the cruciate ligaments lateral ins caused by disruption of the collater ment free bodies in the joint cavit luxating patellae and occasionally mobile menisci However the most c cause is a longitudinal tear of the p

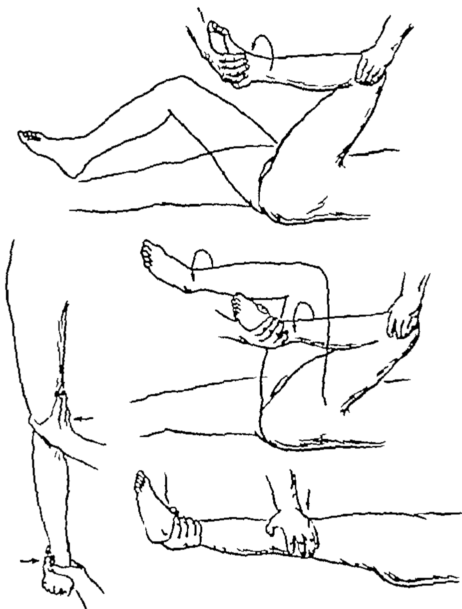


FIG 132 (*Top right*) Fouche's maneuver to detect tear of the posterior segment.

FIG 133 (*Center right*) McMurray's maneuver to detect lesions of the posterior segment.

FIG 134 (*Bottom left*) Compression test to determine which meniscus is implicated

FIG 135 (*Bottom right*) Extension test to determine which meniscus is involved.

segment of a meniscus. The emphasis that Smillie has placed on the close relationship of giving way incidents to tears of the posterior segment has focused the attention of many orthopedic surgeons on this symptom Clinical experience reveals that his observations are correct This may be the only information available which indicates that the meniscus is involved It becomes apparent that other causes capable of producing giving way incidents must be eliminated This however, can be achieved readily by thorough examination of the part and careful interrogation of the patient Demonstration of a click in the joint by special tests establishes the diagnosis.

SPECIAL TEST TO ELICIT "CLICK"

Numerous tests have been conceived to demonstrate lesions of the posterior segment of the menisci Of these Fouche's test and McMurray's test are the most reliable. The former maneuver was described first in the American literature by Dutoit and Enslin in 1945 It is of interest that the two tests are the reverse of one another

FOUCHE'S TEST

In testing for lesions of the posterior segment of the medial meniscus the patient assumes the supine position with the hip and the knee of the affected limb fully flexed (Fig 132) The left fingers of the examiner are placed on the joint line while the right hand firmly grasps the foot which is used to rotate the lower leg internally A complete movement of circumduction is executed starting with the knee fully flexed and terminating with it slightly flexed When the tibia is rotated internally the meniscus is fixed to the head of the tibia and moves with it, at the same time it is displaced forward toward the center of the joint During the maneuver the concave margin of the meniscus which moves forward is nipped between the femoral and the tibial condyles and then recedes backward At this point a click is felt and heard This sound is produced in normal joints and with practice the click associated with the normal meniscus is readily discernible The sound elicited by a torn meniscus varies from a coarse thud when a large ragged tear of the posterior segment is present to a delicate click when a thin strip of fibrocartilage is displaced from the concave margin

The maneuver is reversed when testing for lesions of the posterior segment of the lateral cartilage Now the tibia is held firmly in the position of external rotation in relation to the femur

MC MURRAY'S TEST

In this maneuver the mechanism which caused the meniscal tear is reproduced (Fig 133) The patient lies on his back with the hip and the knee of the affected extremity fully flexed with the heel close to the buttock One hand holds the knee in a fixed position while the other grasps the foot so that it can be used as a lever to rotate the leg either internally or externally External motion is employed to test for lesions of the posterior segment of the internal meniscus and internal rotation for lesions of the posterior segment of the lateral fibrocartilage By rotation of the tibia, the freedom of movement which the menisci naturally have is lessened and they become attached firmly to the tibia and move with it While rotation of the tibia is maintained the joint is extended to a right angle. As the femoral condyles pass over the lesion in the meniscus a click occurs which is felt and may be audible The portion of the meniscus which is compressed by the femur during this maneuver depends upon the degree of flexion of the rotated leg In full flexion the posterior segment is tested, while in flexion approaching the right angle the middle portion is involved The nature of the sound elicited imparts to the examiner a rough conception of the character and the size of the lesion also the approximate location of the lesion may be determined

COMPRESSION TEST

This test is of some value in determining the side of the joint affected particularly in recent injuries (original or recurrent) in which the patient is not able to localize the pain with any certainty It may also be found of value in cases of long standing (Fig. 134) By this maneuver the affected meniscus is compressed and pain is elicited on the implicated side of the joint It is most effective when some abnormality of the joint is present. With the knee extended the lower leg is adducted in testing for the medial meniscus and abducted in testing for the lateral

EXTENSION TEST

Again when there is doubt as to the meniscus involved, particularly after recent injuries, this test may be helpful in isolating the affected structure (Fig 135) Full extension and even slight hyperextension of the joint will initiate pain over the joint line on the side of the torn meniscus Extension of the joint forces the menisci to move forward this test stretches the torn or frayed peripheral attachments of the torn meniscus thereby producing pain

OTHER CAUSES OF CLICKS OR CREPITUS

Sounds varying in character which are unrelated to meniscal tears are heard frequently in the knee joint Notably among these is the rough grating crepitus associated with osteoarthritis of the joint either degenerative or traumatic in origin The sounds arise from changes in the pericapsular tissues and roughening of the articular surfaces of the femur the tibia and the patella In the degenerative type the crepitus is usually bilateral in the traumatic type it is limited to the affected joint

The patellofemoral joint is a common source of bizarre sounds The lesions responsible for the crepitus may be chondromalacia of the patella alone or of both articular surfaces of the patellofemoral joint generalized osteoarthritis of the knee as described above, subluxating patellae and in rare instances osteochondral fractures of the patella.

Osteochondritis of the femoral condyles may give rise to varying degrees of crepitation in children and adults This is unilateral and demonstrable only in the affected joint

It is generally recognized that undue relaxation of the quadriceps and the ligamentous apparatus may be associated with clicks on movement of the joint No specific lesion of the menisci need be present except laxity of its peripheral attachments The clicks are usually bilateral and not associated with pain when they occur this is in contradistinction to clicks associated with torn menisci in which pain or at least some discomfort is experienced by the patient

Snapping tendons in the region of the knee joint may be responsible for unnatural sounds Some patients are able to produce the sounds voluntarily by certain trick movements of the joint in one child the sharp snap sounded like the twang of a bow string. Occasionally in children a thud may be present with flexion and extension of the joint the cause being a discoid meniscus Such sounds in children always should make one suspicious of a congenital discoid meniscus particularly if they occur on the outer side of the knee joint

EXTENSOR AND LIGAMENTOUS APPARATUS

No examination of the knee joint can be considered complete until the status of the quadriceps and the ligamentous apparatus is established A painstaking examination may reveal lesions of the cruciate and the collateral ligaments and undue laxity in the extensor mechanism the capsule and the ligaments These alterations may exist independently of a meniscal tear or may be complications of the lesions following recurrent incidences of giving way and effusion In the latter case analysis of the condition will give the examiner some concept of the amount of improvement that can be

anticipated following removal of the torn meniscus Marked relaxation of the aforementioned structures tends to impede rapid restoration of function to normalcy, in fact, in the presence of advanced alterations normal function may be impossible to achieve, and additional complications such as osteoarthritis may ensue This is true particularly if the knee is forced to perform work which is beyond its functional capacity

MENISCUS PALPABLE AT THE JOINT LINE

Occasionally, the convex periphery of the torn meniscus can be palpated at the joint line With the patient in the supine position with the hip and the knee fully flexed, the examiner's thumb is placed over the joint line at the point of maximum tenderness, the other hand grasps the foot and passively extends and flexes the lower leg while rotating it at the same time The cartilage can be felt under the thumb as it plays back and forth on the tibial plateau In rare instances a long pedunculated central portion of a longitudinal tear which has been severed at its distal or anterior end may be extended toward the periphery passing over or beneath the peripheral portion In 2 cases the mass appeared on the lateral side of the joint anterior to the fibular collateral ligament It was irreducible and painful on pressure a diagnosis of cystic degeneration of the cartilage was made in each instance At operation the true nature of the lesions was established Also the periphery of the meniscus may be forced over the tibial margin to protrude at the joint line It was interesting to note that this occurred in one of the regenerated menisci removed by the author the tumefaction appeared behind the posterior margin of the fibular collateral ligament In another case after several recurrent episodes of locking a mass presented itself in the anteromedial angle of the joint between the inner margin of the ligamentum patellae and the anterior border of the tibial collateral ligament the mass was both visible and palpable Exploration of the joint disclosed a triple longitudinal tear extending far into the anterior segment, the distal ends of the two central portions had become detached, and both meniscal flaps had been extruded toward the periphery of the anterior aspect of the joint where they lay in an entangled ball The appearance of a lump at the joint line may be only transitory usually following an incident of giving way buckling of the joint or actual locking it then suddenly snaps into place or the patient may learn to reduce it by trick movements of the knee or by manual pressure

Clinical Features Peculiar to Tears of the Lateral Meniscus

In general, the mildness of the symptoms is the pertinent feature of lesions of the lateral meniscus in fact, this characteristic is responsible for the high incidence of failure to recognize the true nature of the lesion at the time of the original or subsequent injuries As a rule the initial trauma results in minor tears of the posterior segment with no locking and only minimal pain disability and effusion As the result of repeated trauma to the structure or as the result of normal function the original tear increases in severity, implicating a larger segment of the meniscus eventually it is of sufficient size to produce incidences of buckling pseudo-locking and giving way, thereby interfering markedly with normal function and increasing the disability of the patient

Several factors are responsible for the discrepancy in the intensity of the symptoms and the disability incident to lesions of the medial and the lateral menisci The increase in mobility of the lateral meniscus as compared with the medial renders it less liable to trappings between the femoral and the tibial condyles Also this characteristic of the lateral fibrocartilage prevents undue tearing and stretching of the synovial and the capsular attachments hence, less pain is elicited and only minimally synovial reaction ensues than is noted in lesions of

the medial structures The latter is evidenced by the small amount (and in some instances the absence) of synovial effusion *which accompanies injuries of the lateral* fibrocartilage The more circular configuration of the lateral meniscus is a factor in *limiting longitudinal tears to the posterior* segment furthermore this characteristic in a measure precludes displacement of the central portion of a tear toward the center of the joint Hence true locking at the original or subsequent injuries is not a frequent occurrence. It must be added that the popliteus muscle through its fascial attachments and the ligaments of Wrisberg and Humphry resists forward displacement of the posterior segment this action is another safeguard of the lateral meniscus

Evaluation of Original Injury

It was stated previously that in some cases examined shortly after an original injury the diagnosis is established readily provided that the patient relates an undisputable history of a rotatory strain of the knee joint resulting in mechanical true locking or of crunching sensation in the joint followed by synovial effusion and that there is still evidence of definite localized tenderness over the joint line of the affected meniscus On the other hand the problem may be exceedingly difficult when the patient is examined for the first time several weeks after the injury and gives a vague history of the incident and no characteristic signs except a synovial effusion are demonstrable The patient is unable to determine on which side of the joint the pain was more pronounced and palpation fails to elicit sufficient tenderness at any one point over the medial or the lateral joint to incriminate one of the menisci unequivocally It becomes apparent that under such circumstances it is impossible to determine the type the severity or the location of the lesion Surgical exploration at this time is not justified and a course of "watchful waiting should be pursued Attention should be directed to the restoration of good quadriceps tone and power and the eradication of the associated traumatic synovitis After this is achieved the patient should be encouraged to resume his normal activities If he has sustained a tear of one of the menisci early or late clinical manifestations pointing to the torn structure will become evident and of course should be treated accordingly

Recurrent Injuries

The pattern of the clinical picture varies considerably after the original injury It was stated previously that symptoms in recurrent incidences rarely approach the severity of the first episode In a certain group of cases transitory locking and giving way of the knee joint are frequent occurrences over a period of several years eventually complete locking of the joint occurs Frequently the joint of these patients exhibits varying degrees of osteoarthritis In another group true locking never occurs There are numerous incidences of giving way accompanied by synovial effusion As in the previous group these cases are likely to develop chronic synovitis osteoarthritis *relaxation of the ligamentous and the exten*sor apparatus and occasionally tearing of the second meniscus in the same joint Finally in the majority of patients the subsequent clinical course is characterized by repeated episodes of true locking The incidence of mechanical locking in recurrent cases is far greater than that in the original injury Many of the lockings are transitory in nature and often the patients learn to unlock the joint by trick movements of the limb or by manual reduction Such lockings usually are not accompanied by severe pain or joint reaction however occasionally lockings occurring after long intervals may be associated with severe pain and large effusions approaching the intensity of the original injury

Lesions of Both Menisci

The incidence of coexistent lesions of both menisci is *sufficiently high to force the*

surgeon to suspect its occurrence in all recurrent cases, in the series reported herein, there were 16 cases The diagnosis is often difficult to establish because the intensity of the symptoms may be pronounced on one side and only minimal on the opposite side Although it is possible to sustain double tears at the initial injury, this occurrence is relatively rare Generally, the second meniscus is injured subsequently to the original injury In some patients the severity of the first incident may not be recognized the patient may have in addition to a tear of the meniscus concomitant injuries of the tibial collateral ligament or of the anterior cruciate ligament or both. Failure to institute adequate treatment results in an unstable knee joint in which there are numerous incidents of giving way pseudolocking and recurrent effusions. This train of events favors relaxation of the capsular and the ligamentous mechanisms, insufficiency of the quadriceps apparatus and softening of the menisci In the light of these alterations it becomes apparent that the second meniscus is rendered vulnerable to injury and that tearing of the structure may result Such a sequence of events may follow a lesion of one meniscus without implication of other structures or it may occur in cases in which a meniscectomy has been performed and inadequate postoperative management has failed to restore maximum stability of the knee and optimum quadriceps power Such knees are liable to recurrent episodes of giving way synovial effusions and hence injury to the remaining fibrocartilage Lastly failure to remove the cartilage in toto by leaving the posterior segment behind may result in a postoperative clinical course similar to that described above this predisposes the patient to injury of the second meniscus

HYPERMOBILE MENISCI

It is generally accepted that hypermobility of the menisci does exist and is capable of producing symptoms of internal derangement of the knee joint It is observed most frequently in young women with relaxation of the capsular tissues and the extensor apparatus Abnormal mobility of the menisci may be a sequel of recurrent synovial effusions producing stretching of coronary ligaments and other peripheral attachments of the menisci However close scrutiny of the inside of the knee joint and an apparently normal meniscus following its removal in many instances may disclose a definite pathologic process responsible for the clinical manifestations. Too often, failure to investigate the inside of the knee joint thoroughly or to recognize and assess existing lesions adequately leads to an erroneous diagnosis of hypermobile menisci the abnormal mobility is the result of severe stretching and in some instances actual tearing of the peripheral attachments of the structures by repeated rotatory strains on the flexed knee Such alterations may give rise to symptoms of internal derangement and may predispose the meniscus to more severe injuries In the author's series, 29 normal menisci were removed Careful investigation at the time of operation of the joints and of the excised menisci failed to reveal evidence of any pathologic process except unusual mobility of the fibrocartilage Sixteen of the 29 cases were checked in a subsequent follow up study of these 11 were completely alleviated of the symptoms, 3 were improved and 2 were not improved

DIFFERENTIAL DIAGNOSIS

Before arriving at a diagnosis of tears of the menisci several important entities must be considered and eliminated this is particularly true in cases which fail to provide a classical clinical picture of a torn meniscus The lesions which demand attention are

1 Lesions of the infrapatellar fat pad
2 Cysts of the menisci
3 Parameniscal cysts
4 Discoid menisci
5 Regenerated meniscus

the medial structures The latter is evidenced by the small amount (and in some instances the absence) of synovial effusion which accompanies injuries of the lateral fibrocartilage *The more circular configuration of the lateral meniscus is a factor in limiting longitudinal tears to the posterior segment furthermore this characteristic in* a measure precludes displacement of the central portion of a tear toward the center of the joint Hence *true locking at the* original or subsequent injuries is not a frequent occurrence It must be added that the popliteus muscle through its fascial attachments and the ligaments of Wrisberg and Humphry resists forward displacement of the posterior segment this action is another safeguard of the lateral meniscus

Evaluation of Original Injury

It was stated previously that in some cases examined shortly after an original injury the diagnosis is established readily provided that the patient relates an undisputable history of a rotatory strain of the knee joint resulting in mechanical true locking or of crunching sensation in the joint followed by synovial effusion and that there is still evidence of definite localized tenderness over the joint line of the affected meniscus On the other hand, the problem may be exceedingly difficult when the patient is *examined for the first time several weeks* after the injury and gives a vague history of the incident and no characteristic signs *except a synovial effusion are demonstrable* The patient is unable to determine on which side of the joint the pain was more pronounced and palpation fails to elicit sufficient tenderness at any one point over the medial or the lateral joint to incriminate one of the menisci unequivocally It becomes apparent that under such circumstances it is impossible to determine the type the severity or the location of the lesion Surgical exploration at this time is not justified and a course of watchful waiting" should be pursued Attention should be directed to the restoration of good quadriceps tone and power and the eradication of the associated traumatic synovitis After this is achieved, the patient should be encouraged to resume his normal activities. *If he has sustained a tear of one of the menisci early or late clinical manifestations pointing to the torn structure will become evident* and of course should be treated accordingly

Recurrent Injuries

The pattern of the clinical picture varies considerably after the original injury It was stated previously that *symptoms in recurrent incidences rarely approach the severity* of the first episode In a certain group of cases transitory locking and giving way of the knee joint are frequent occurrences over a period of several years eventually complete locking of the joint occurs. Frequently the joint of these patients exhibits varying degrees of osteoarthritis In another group true locking never occurs There are numerous incidences of giving way accompanied by synovial effusion As in the previous group these cases are likely to develop chronic synovitis osteoarthritis relaxation of the ligamentous and the extensor apparatus and *occasionally tearing of the second meniscus in the same joint* Finally in the majority of patients the subsequent clinical course is characterized by *repeated episodes of true locking* The incidence of mechanical locking in recurrent cases is far greater than that in the original injury Many of the lockings are transitory in nature and often the patients learn to unlock the joint by trick movements of the limb or by manual reduction Such lockings usually are not accompanied by severe pain or joint reaction however occasionally lockings occurring after long intervals may be associated with severe pain and large effusions approaching the intensity of the original injury

LESIONS OF BOTH MENISCI

The incidence of coexistent lesions of *both menisci is sufficiently high to force the*

surgeon to suspect its occurrence in all recurrent cases, in the series reported herein, there were 16 cases The diagnosis is often difficult to establish because the intensity of the symptoms may be pronounced on one side and only minimal on the opposite side. Although it is possible to sustain double tears at the initial injury, this occurrence is relatively rare Generally, the second meniscus is injured subsequently to the original injury In some patients the severity of the first incident may not be recognized, the patient may have, in addition to a tear of the meniscus, concomitant injuries of the tibial collateral ligament or of the anterior cruciate ligament or both Failure to institute adequate treatment results in an unstable knee joint in which there are numerous incidents of giving way pseudolocking and recurrent effusions This train of events favors relaxation of the capsular and the ligamentous mechanisms insufficiency of the quadriceps apparatus and softening of the menisci In the light of these alterations, it becomes apparent that the second meniscus is rendered vulnerable to injury and that tearing of the structure may result. Such a sequence of events may follow a lesion of one meniscus without implication of other structures or it may occur in cases in which a meniscectomy has been performed and inadequate postoperative management has failed to restore maximum stability of the knee and optimum quadriceps power Such knees are liable to recurrent episodes of giving way synovial effusions and hence injury to the remaining fibrocartilage Lastly failure to remove the cartilage in toto by leaving the posterior segment behind may result in a postoperative clinical course similar to that described above this predisposes the patient to injury of the second meniscus

HYPERMOBILE MENISCI

It is generally accepted that hypermobility of the menisci does exist and is capable of producing symptoms of internal derangement of the knee joint It is observed most frequently in young women with relaxation of the capsular tissues and the extensor apparatus Abnormal mobility of the menisci may be a sequel of recurrent synovial effusions producing stretching of coronary ligaments and other peripheral attachments of the menisci However, close scrutiny of the inside of the knee joint and an apparently normal meniscus following its removal in many instances may disclose a definite pathologic process responsible for the clinical manifestations. Too often, failure to investigate the inside of the knee joint thoroughly or to recognize and assess existing lesions adequately leads to an erroneous diagnosis of hypermobile menisci the abnormal mobility is the result of severe stretching and in some instances actual tearing of the peripheral attachments of the structures by repeated rotatory strains on the flexed knee. Such alterations may give rise to symptoms of internal derangement and may predispose the meniscus to more severe injuries. In the author's series, 29 normal menisci were removed Careful investigation at the time of operation of the joints and of the excised menisci failed to reveal evidence of any pathologic process except unusual mobility of the fibrocartilage Sixteen of the 29 cases were checked in a subsequent follow up study of these 11 were completely alleviated of the symptoms 3 were improved, and 2 were not improved.

DIFFERENTIAL DIAGNOSIS

Before arriving at a diagnosis of tears of the menisci several important entities must be considered and eliminated this is particularly true in cases which fail to provide a classical clinical picture of a torn meniscus The lesions which demand attention are

1 Lesions of the infrapatellar fat pad
2 Cysts of the menisci
3 Parameniscal cysts
4 Discoid menisci
5 Regenerated meniscus

6 Incomplete removal of torn meniscus
7 Lesions of collateral and cruciate ligaments
8 Fractures—tibial spine and osteochondral fractures of patella
9 Loose bodies
10 Recurrent dislocation of patella
11 Osteoarthritis
12 Periarticular lesions—bursae and exostoses
13 Chondromalacia patellae

Lesions of the Infrapatellar Fat Pad

It was noted previously that a large pyramid shaped pad of fat occupies the interval between the lower border of the patella and the anterior border of the articular surface of the tibia. This fat pad is invested by synovial membranes on both sides of the patella and close to its articular margin which fall into loose folds designated as alar folds, these converge below to form a median fold the ligamentum mucosum which extends to the anterior region of the intercondyloid fossa of the femur in relation to both the anterior and the posterior cruciate ligaments From the inferior portion of the infrapatellar fat pad loose folds of synovialis and fat tissue project inward covering the anterior portions of the menisci these processes have been designated as semilunar pads (Fisher) Some fibers of the articularis genu muscle continue downward and blend with the proximal portion of the fat pad

During flexion of the knee joint the alar folds become taut and tend to displace the fat pad backward into the joint In extension the quadriceps muscle pulls upward on the patella in turn the patella elevates the fat pad through its attachment to the alar folds Upward displacement is enhanced further by contraction of the articularis genu muscle In complete extension the ligament the capsule and the quadriceps mechanism all become tense thereby compressing the fat pad into a smaller compartment From these observations it becomes obvious that in the presence of some disorder in the stabilizing mechanism of the knee joint such as a poor quadriceps effusions and relaxation of the reinforcing structures of the joint, the synovial fringes or portions of the fat pad may be trapped between the articular surfaces of the femur and the tibia also a hypertrophied fat pad is vulnerable to the same mechanism of injury This results in hemorrhage synovial effusion and thickening of the fat pad Repeated incidences result in hypertrophy and fibrosis of the structure In addition to this form of injury the semilunar pads may be crushed by the same mechanism which crushes the anterior segments of the menisci In the terminal phase of extension (screw home movement) the anterior portion of the inner femoral condyle glides over the inner semilunar pad and not over the superior surface of the anterior segment of the meniscus. This is readily demonstrable in fresh cadaver specimens of knee joints and has been observed many times by the author Fortunately traumatic lesions of the fat pad and its processes are not encountered frequently in normal joints as a rule they occur in joints impaired by degenerative alterations such as osteo-arthritis chronic villous synovitis and in joints rendered unstable by an inadequate extensor apparatus. The very infrequency of the lesions is one reason that they are commonly overlooked The nature of the symptoms that they produce is similar to tears of the menisci without true locking

Clinical Features

Two varieties of lesions of the fat pad are discernible—chronic and acute In the chronic cases the pertinent clinical manifestations are vague pain in the retropatellar region which is accentuated by recurrent incidents of giving way and varying amounts of synovial effusions accompanying the incidents Depending upon the degree of dysfunction of the knee joint associated with the disorder wasting of the quadriceps in varying degrees is present Generally in

between episodes of nipping of the fat pad regional tenderness is not a constant finding, however, immediately after a recurrent incident, tenderness may be elicited on pressure in both the anteromedial and the anterolateral joint angles. In cases of marked hypertrophy of the fat pad, some increased fullness is discernible on either side of the patellar tendon This condition may be difficult to distinguish from a cystic mass in the retropatellar region arising from the anterior segment of the menisci or from the infrapatellar pad per se Here one can arrive only at a presumptive diagnosis The final diagnosis can be established solely by exploration of the affected region.

In the acute cases the aforementioned findings are accentuated In addition forceful extension of the knee or against resistance is invariably associated with pain in the retropatellar region These maneuvers tend to compress the swollen and hemorrhagic fat pad into a smaller compartment

Crushing of the semilunar processes more closely simulates lesions of the anterior horns of the menisci than nipping of the synovial fringes and the alar folds The cardinal features are pain on forceful extension or on extension against resistance a sense of instability caused primarily by incidents of giving way and a sensation of something slipping inside the joint and the appearance of synovial effusions after any form of activity If the screw home movement is intensified acute pain may be elicited This maneuver is accomplished by forcefully rotating the tibia externally while the knee is in full extension

TREATMENT

Conservative management should aim to reduce the swelling and the thickening of synovial tags and of the infrapatellar fat pad as a whole and also to restore the quadriceps mechanism to normalcy This is achieved by nonweight bearing exercises designed to increase tone and volume in the quadriceps muscle and to eliminate exercises and activity which predispose the structures to crushing and nipping It becomes obvious that in the event that conservative treatment fails to afford the desired results, excision of the pathologic processes, the hypertrophied tag and the folds is justifiable A median parapatellar incision provides ample exposure of the affected region and also of the articular surface of the patella

CYSTS OF THE MENISCI

Cystic degeneration of the menisci usually is encountered in the third decade It was stated previously that in the author's series the ages ranged from 17 to 58, the average being 26 5, the youngest patient in this series was a 17 year-old girl with bilateral lesions. The lesions occur more frequently in the male than in the female, in the series reported herein there were 34 males and 14 females The lateral meniscus was implicated in 84 per cent of the cases and the medial meniscus in 16 per cent Unless there is a concomitant tear of the meniscus, the patient exhibits no clinical features of internal derangement of the knee joint. The cardinal features are a constant, deep-seated pain and the presence of a swelling on the outer side of the joint Often the patient will focus the attention of the examiner on the swelling Characteristically of the lesion, the symptoms are never so severe that the patient is disabled seriously also the pain is accentuated by activity, particularly arduous sports and is diminished in intensity by rest The patient frequently volunteers the information that the tumefaction varies in size from time to time usually being larger after exercises. An example of this point was provided by a young male who exhibited on the first examination a large swelling the size of a walnut on the outer side of the knee joint He was admitted to the hospital to have the cystic mass removed Ten days later when the patient was examined prior to surgery the mass was barely perceptible in fact, the



FIG 136 Cystic degeneration of the lateral meniscus note the tense rounded mass anterior to and beneath the fibular collateral ligament

question of a possible mistake in diagnosis arose However at operation the diagnosis was confirmed Small cysts may not cause real pain but rather a feeling of discomfort and tightness on the lateral aspect of the knee Occasionally the pain is accentuated when the knee is extended fully This is particularly true of large cysts arising in the lateral meniscus The size of the lesion is decidedly variable measuring from 1 cm. to 6 or 8 cm. along the largest dimension small cysts are encountered more commonly than large cysts

Examination of the lesions of the lateral fibrocartilage reveals that the smaller cysts usually are situated on the joint line imme diately in front of the fibular collateral liga ment they are exceedingly firm and are fixed to the surrounding tissues There may be present a slight bulge of the lateral liga ment (Fig 136) The larger cysts may found on the joint line or they may com lie on the anterolateral surface of the berosity of the tibia or to occupy a posit above the joint line on the lateral surf of the condyle of the femur These cysts slightly more mobile and less firm than smaller variety however, the consiste of the larger lesions is a decidedly varia feature Without exception flexion ca a reduction in the size of the cysts, w extension produces an increase in the s Firm pressure over the swelling elicits t derness. This is more pronounced when lesions have increased in size following so form of activity Compression of the fib cartilage by forcefully abducting the co pletely extended lower leg always produ pain on the lateral aspect of the joint intensity of the pain may be severe if maneuver is performed while the cysts enlarged A lesion commonly associated w cysts of the lateral fibrocartilage is an complete oblique or transverse tear of t concave margin of the meniscus (Fig 11 When such a lesion is present such featu of internal derangement as incidents giving way a sense of instability in the fected extremity and recurrent effusions superimposed on those resulting from t cysts

Cysts of the medial meniscus are le common but are usually larger and mo mobile than those associated with the la eral Also they have a tendency to penetra the tibial collateral ligament from whi site they may extend either anteriorly posteriorly the latter path is more co mon so that the cysts may come to lie the posteromedial or even the posterior a pect of the medial femoral condyle

Occasionally the clinical picture is co fused by the development of cysts from t posterior or the anterior horns of the m nisci Lesions of the anterior horns m reach relatively large dimensions diss through the capsule and occupy a positi under the deep fascia of the leg on eith

side of the patellar tendon Since they are not under great tension, pain is not a prominent feature, they may lead to the erroneous impression that one is dealing with a lesion of the infrapatellar fat pad (Fig 118)

Concealed cysts of the lateral meniscus have been reported in the literature These are rare lesions and arise from the medial (free) border of the lateral fibrocartilage, extend into the center of the joint space and lie in relation to the cruciate ligament The first case was reported by Ollerenshaw (1935) in a girl 11 years old A second case was recorded by Dittrick (1946), in this instance the cyst arose from the anterior horn of the lateral meniscus with a detached hypermobile anterior segment. The cyst retained an intracapsular position As stated previously the author has encountered one case of a cyst originating from the anterior segment of the meniscus however this lesion did not retain an intracapsular position (Fig 118)

PARAMENISCAL CYSTS

The lesions arise from bursae or prolongations of synovial pouches beneath the fibular collateral ligament. It is difficult to distinguish these swellings from true cystic degenerative changes of the fibrocartilage because the physical findings are identical The true nature of the lesions may be determined only at operation when it becomes apparent that the meniscus is not implicated The author has reported 6 such cases 1 being associated with a discoid meniscus A 5 year follow-up study of these cases disclosed no recurrence of the lesion in any of the cases at operation only the cystic masses had been excised and the menisci had not been removed

Displacement of a portion of the torn meniscus toward the periphery of the joint may produce a swelling in the region of the collateral ligaments which may coincide with cysts of the fibrocartilage Long pedunculated tags produced by a transverse tear superimposed on a longitudinal tear are the more common lesions capable of protruding at the joint line They may be based anteriorly or posteriorly and may cross over the superior surface or pass beneath the inferior surface of the meniscus (Fig 101) Like cysts, these lesions produce a firm swelling which tends to recede on flexion and to become more prominent on extension of the knee joint

Smillie has described another interesting meniscal lesion which is capable of simulating cysts This is an incomplete oblique tear with a horizontal cleavage in the substance of the parent structure situated opposite the posterior lip of the tear the posterior lip of the oblique tear passes through this plane of cleavage to protrude at the joint line, producing in this region a firm tumefaction which recedes with flexion and increases its dimensions on extension The author never has encountered this lesion Occasionally, the convex peripheral portion of the disk may project over the rim of the tuberosity of the tibia producing a swelling on the lateral aspect of the joint. The same effect may be produced by a longitudinal split in the periphery of the meniscus with outward displacement of the peripheral portion (Fig 111)

Intracapsular loose bodies which have attained attachment in the region of the lateral aspect of the joint may produce palpable and visible swellings in this region which may be interpreted erroneously as cysts of the cartilage Roentgenographic study should establish the diagnosis Bony excrescences and osteophytes formed at the osteochondral junction of the tibia or the femur on the lateral aspect of the knee joint likewise may be very misleading particularly when one knows that the above alterations may be incident to cystic degenerations of the menisci

DISCOID MENISCI

The symptoms and the signs incident to congenital discoid menisci do not permit a

correct diagnosis in the majority of the cases It is now generally recognized that the loud thud produced by flexion and extension of the knee joint and believed at one time to be *pathognomonic of discoid* menisci is demonstrable in a very small percentage of the cases. The lesions are encountered frequently in children, however many are observed in the older age periods In the author s series the age ranged from 6 to 43 As previously noted, there were 10 males and 8 females and 17 lateral and 1 medial *discoid menisci* The right knee was involved in 10 cases and the left in 8 there was 1 bilateral case No case was encountered in which there existed both a medial and a lateral discoid meniscus, however such cases have been recorded in the literature

When a loud thud or a snap is present, particularly in children and is associated with vague symptoms of internal derangement in the lateral compartment of the joint a presumptive diagnosis of a discoid cartilage should be made In most cases *symptoms of internal derangement, mild in* nature, are the only features present and for this reason the true nature of the lesion is overlooked frequently Tears associated with hypermobility are common alterations in discoid menisci these alterations may be responsible for a clinical picture resembling tears of the normal structures and hence may lead to an *incorrect diagnosis* In addition cystic degeneration of congenital discoid menisci is a relatively common occurrence this associated feature may be manifested clinically overshadowing the presence of the malformed fibrocartilage

The mechanism whereby the audible snap or the thud is produced is described best by Smillie He points out that the sound *is the* result of sudden alteration of the relationship between the meniscus and the condyles of the femur and the tibia The thud occurs at the instant the condyle of the femur rides over the ridge when the meniscus is projected forward or backward There are two varieties of ridges One is formed by a mound of fibrocartilage situated along the anterior margin of the *indentation in the* substance of the meniscus produced by downward pressure of the femur the other comprises the thickened anterior peripheral margin of the meniscus Under normal circumstances the meniscus moves backward and forward with the femoral condyle on extension and flexion of the joint As the *femoral condyle comes to lie deeper in the* substance of the meniscus stretching of the peripheral attachments of the fibrocartilage occurs because now it must follow more closely the movements of the femoral condyle Some minor injury occurring just short of full extension may force the femoral condyle over the ridge, driving the *meniscus backward and thereby stretching* still further or even tearing its anterior peripheral attachments The meniscus is forced forward to its anatomic position when the leg is flexed and at a point short of full flexion the condyle of the femur rides over the ridge projecting the meniscus in a forward direction It becomes apparent that *repetition of the above mechanism results* in pronounced hypermobility of the meniscus so that the most trivial incident may allow the condyle to ride over the ridge hence producing the snap In fact many of the patients are capable of producing the sound voluntarily (Fig 121)

Regenerated Menisci

Experimental and clinical evidence discloses that following meniscectomy the structure is replaced by a replica of fibrous tissue After properly performed operations the incidence of recurrent internal derangements is exceedingly small leading one to conclude that the new structure is less vulnerable to injury than the original Study of the reformed meniscus reveals that it is smaller in its breadth and width and more firmly attached to the capsule than the normal fibrocartilage This last feature allows it less freedom of motion In the light of these observations it becomes apparent that the replica is less liable to injury than the

normal structure, provided that no other factors exist which might predispose it to trappings between the femoral and the tibial condyles

Factors which tend to reduce the stability of the knee joint prejudice the integrity of the replica The most common causes are associated tear of the anterior cruciate liga ment general relaxation of the extensor mechanism and subluxating patellae The author has encountered lesions of regener ated menisci in which one or two of the above abnormalities were present and were believed to be directly responsible for the ensuing lesions of the fibrous structures The author has had the unique experience of encountering a torn regenerated menis cus in a patient from whose knee he had removed the original structure 3 years prior to the second operation The patient was a young marine aged 23 a medial meniscus with a bucket handle tear had been re moved in toto in one of the naval hospitals in 1945 At the time of that operation it was noted that an associated frayed anterior cruciate ligament was present Following meniscectomy a concerted effort was made to develop power in the quadriceps beyond normal This was done with the hope that the strong quadriceps would compensate for the defective anterior cruciate ligament thereby providing sufficient stability to the knee joint. In April, 1948, he was admitted to a civilian hospital with a history of re current incidents of giving way followed by effusion. The patient had been free of symptoms for 2 years following the first operation He then sustained a severe twist ing injury to the knee while playing foot ball Following this episode, he noted a sense of instability in the knee joint and experienced repeated incidents of giving way Examination disclosed a moderately swollen knee an advanced relaxation of the quadriceps and the ligamentous apparatus and a positive anterior draw sign At opera tion a completely reformed meniscus was found with an incomplete longitudinal tear on the superior surface and two small pe dunculated tags based anterior on the in ferior surface (Fig 85)

Figure 86 depicts a tear in the posterior segment of a regenerated meniscus in which the large pedunculated tag lay across the superior surface of the meniscus and pro jected at the periphery behind the posterior margin of the tibial collateral ligament It led to the erroneous diagnosis of a cyst in this region arising from the remnants of the original structure which had been left be hind following meniscectomy

Incomplete Removal of Torn Meniscus

It is common knowledge that many sur geons, either volitionally or because of tech nical difficulties, fail to remove the torn meniscus in toto Some remove only the central portion of a bucket handle tear, others leave the posterior segment behind Although many of these patients are re lieved in a measure of some of the symp toms such as locking most of them still exhibit manifestations of internal derange ment The cardinal features are giving way or buckling of the knee joint a sense of instability and recurrent effusions Gener ally the signs and the symptoms point to implication of the posterior segment In such cases Fouche's and McMurray's tests should be employed to elicit the diagnostic click in the posterior compartment of the joint In the differential diagnosis other le sions producing the same train of symptoms and signs must be considered, such as an insufficient quadriceps muscle recurrent subluxating patellae and loose bodies Fig ure 84 shows the regenerated anterior por tion of a medial meniscus which is con tinuous with the posterior segment of the original structure The peripheral attach ments of the posterior segment were atten uated markedly and both surfaces show evidence of repeated trappings and macera tion however no longitudinal tears are demonstrable

Lesions of Collateral and Cruciate Ligaments

These lesions may exist singly or as le-

sions concomitant with tears of the menisci They are discussed fully in the chapter dealing with injuries of the ligaments However, at this point it should be pointed out that rupture or strains of the deep fibers of the tibial collateral ligament are frequently associated with lesions of tears of the medial fibrocartilage. The cardinal features of this entity are maximum tenderness over the ligament on a level of the joint line and pain when the extended leg is abducted forcefully However, these signs also are present when the meniscus is implicated making the diagnosis difficult In the absence of tears of the meniscus no features consistent with internal derangement are present.

Often, lesions of the anterior cruciate are associated with medial meniscal tears, and in some instances both injuries plus a rupture of the tibial collateral ligament may be present Instead of a torn anterior cruciate ligament one may encounter a fracture or an avulsion of the tibial spine In rare instances both cruciates may be torn The surgeon should be aware constantly of the many combinations of lesions that may exist only in this way can he plan an adequate course of treatment

Subsequently the more common combinations and their management will be discussed

Fractures of Tibial Spine and Osteochondral Fractures of Patella

As noted above fracture or avulsion of the tibial spine may be a lesion coexistent with meniscal tears and is the equivalent of a rupture of the anterior cruciate ligament. Osteochondral fractures of the patella associated with lesions of the fibrocartilage have been recorded in the literature and also observed by the author The possibility of coexisting lesions makes it mandatory that in every case of meniscectomy the patella be scrutinized carefully preoperatively by roentgenographic study and during the operation by either visualization or palpation of the articular cartilage of the patella.

Other Diagnostic Aids

Roentgenographic Studies. Routine roentgenograms do not depict lesions of the menisci their value lies in eliminating other pathologic disorders which may simulate the clinical picture of torn menisci Also, concomitant lesions with torn menisci may be uncovered Such abnormalities as *osteochondritis dissecans* loose bodies, subluxating patellae osteochondral fractures of the patella and fractures of the tibial spine are readily detectable by roentgenographic studies Failure to recognize these lesions when they exist singly or are associated with meniscal tears may be responsible for a poor result following removal of a meniscus which was considered preoperatively to be the sole causative agent for the internal derangement. In the light of this information it becomes apparent that routine roentgenograms comprising anteroposterior lateral and axial views should be taken of every case exhibiting signs and symptoms consistent with a lesion of the menisci

Pneumoroentgenography Recently much has been written on pneumoroentgenography as a valuable aid in determining the types and the locations of meniscal lesions and to establish the presence of other intra-articular lesions such as ruptures of the cruciate ligaments Some workers employ one of the iodized oils as the contrast medium and report a high incidence of accuracy in making the correct diagnosis. The author has experimented with several of the various technics and has come to the conclusion that the routine use of these methods is not indicated The technics and the interpretations of the roentgenograms are difficult to master and do not influence the ultimate decision relative to the management of the individual case The information provided by a history taken carefully and a physical examination executed meticulously suffices to make the correct diagnosis in the majority of the cases of meniscal lesions Moreover in a high per

centage of cases of atypical internal derangements of the knee joint arthrography fails to establish the correct diagnosis, making it apparent that the use of this method as a routine diagnostic aid is not warranted The author is of the opinion that in atypical cases presenting difficult diagnostic problems exploration of the joint is indicated, provided that the symptoms are sufficiently severe to justify the procedure

TREATMENT OF TRAUMATIC LESIONS OF THE MENISCI

General Considerations

Experimental and clinical observations have formulated the present-day concept of treatment of injuries of the menisci These observations emphasize the futility of conservative measures in the majority of meniscal lesions. It has been recorded already that King's investigation proved conclusively that tears in the menisci which fail to extend into the vascular convex periphery of the fibrocartilages or into the peripheral attachments of the structures do not heal Also lesions which communicate with the vascular zones heal, provided that the limb is immobilized adequately for a sufficient period of time (3 weeks) Clinical experience supports these observations. Unfortunately, the majority of tears of any practical significance occurring in humans are situated in the avascular regions of the menisci where healing cannot be expected It becomes obvious that from a practical viewpoint conservative management is of doubtful value except as a temporary measure Also, if lesions of the menisci of sufficient severity to cause symptoms of internal derangement are treated conservatively recurrent incidents must be anticipated Finally insistence on conservative therapy invariably results in irreversible secondary osteo-arthritic changes in the joint, pronounced insufficiency of the extensor apparatus and relaxation of the ligaments and the capsule All of these factors, singly or in combination, are capable of producing marked disability of the knee joint. In addition, it is generally known that if meniscectomy is performed soon after the initial injury, the incidence of good results is far greater than if the meniscus is removed after an interval of months or years After secondary alterations have taken place in the cartilaginous elements and in the supportive structures of the joint, removal of the torn meniscus will not restore the joint to complete normalcy Although the intensity of the symptoms may be decreased some impairment of function is usual the degree of disability parallels the severity of the irreparable damage to the joint as a whole In order to prevent the aforementioned unfavorable sequelae, early surgical excision of the affected meniscus is the treatment of choice. However, there are instances in which conservative measures are justified, either as a preliminary or a definitive form of treatment.

Conservative Management

Frequently a definite diagnosis cannot be established following an initial injury Although one may suspect a tear of one of the menisci the available clinical and roentgenographic evidence may be inconclusive. Also, doubt as to the true nature of the lesion may exist after the acute reaction has subsided In such cases a conservative program should be adopted until subsequent events permit one to arrive at an accurate estimate of the original lesion Cases falling into this category should be treated as cases of traumatic synovitis. After the effusion is absorbed and the quadriceps tone is restored to normalcy normal activity should be pursued If recurrent episodes of locking or giving way accompanied by effusion occur the case should be re-examined carefully and the diagnosis determined If one of the menisci is believed to be the responsible agent for the internal derangement it should be removed

Occasionally, lesions of some of the sup-

porting structures of the joint may occur in conjunction with tears of the menisci the most common abnormalities are tears of the tibial collateral ligament and tears of the cruciate ligaments Unless true locking is evident, these lesions may obscure the meniscal tears In the absence of mechanical locking, cases of meniscal tears associated with one or both of the above complications should be treated conservatively until the acute reaction subsides A waiting period of 2 to 3 weeks allows synovial effusions to be absorbed and tissues laden with fluid and blood to approach a state of normalcy The detailed management of combined lesions of the ligaments is discussed fully in Chapter 8 'Traumatic Lesions of the Ligaments" When coexisting lesions of the ligaments are associated with a locked knee joint it is imperative that the knee be unlocked first The subsequent treatment should be along the lines outlined above In general the goal of conservative treatment in recent meniscal injuries with implication of the supporting structure is to preserve the efficiency of the quadriceps mechanism and to induce rapid restoration of all tissues to normal This is achieved best by promoting absorption of synovial effusion by compression bandages and in cases of large effusions by aspiration of the joint Weight bearing during the early period of treatment should be prohibited Quadriceps exercises should be commenced immediately and performed regularly only by such a regimen are the tone and the volume of the quadriceps maintained at a level approaching normal As a rule the optimum time for surgical intervention is 2 or 3 weeks after the original injury The author recommends this same mode of preoperative management for locked knee joints without impairment of the supportive structures, which are reduced spontaneously or manually

THE LOCKED KNEE JOINT

The necessity of immediate reduction of a displaced torn cartilage is understood readily when one observes the changes that occur in the fibrocartilage in a joint that has been locked for several days Upon opening the joint capsule varying amounts of yellow viscid synovial fluid escape The torn meniscus has lost its sharply defined configuration and appears to be thickened soft and edematous It is no longer firm and

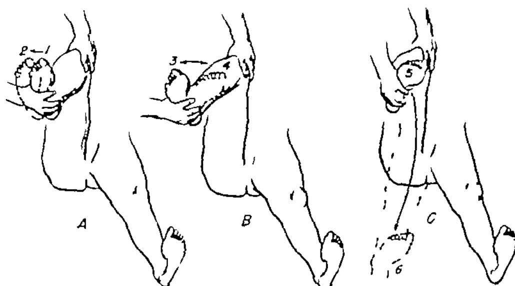


Fig 137 Reduction of a locked medial meniscus. (A) With the hip and the knee flexed, first the leg is abducted (B) while abduction is maintained the leg is rotated internally and externally (C) When the maximum amount of internal rotation is attained the leg is extended suddenly For locking due to a lateral meniscus the above procedure is reversed

elastic but instead is soft and friable in cases of long standing It becomes apparent that the structure is not capable of withstanding even minor degrees of compression without crushing of its substance or extension of the existing tear It also becomes obvious that these alterations impede restoration of the displaced structure to its anatomic position In the light of these observations the wisdom of reducing a torn meniscus as soon as possible following the locking incident becomes self-evident. Moreover, the maneuvers designed to attain reduction of the displaced fragment must be executed gently without undue force Severe compression by the femoral condyle on the anterior portion of the meniscus not only may result in a forward extension of the tear into the anterior segment, but also the central concave fragment may remain in relation to the inner aspect of the condyle of the femur This allows some increase in the range of extension but not complete extension The author has encountered several cases in which complete extension was obtained following manipulation however subsequent removal of the menisci disclosed that the tears extended into the anterior horns, and the central fragment became displaced permanently in the intercondylar notch of the femur and fixed to the cruciate ligament.

TECHNIC OF REDUCTION

Reduction of a dislocated meniscus is performed with the reservation that it is a temporary measure designed to relieve the patient of pain and to prevent further alterations in the displaced structure (Fig 137) Inasmuch as healing will not occur after replacement of the meniscus the patient should be made aware of the purpose of this preliminary procedure and should be informed that surgical removal of the meniscus at the optimum time is essential in order to restore maximum function in the knee joint.

Generally an anesthetic is unnecessary however in apprehensive patients or in difficult cases a general anesthesia will facilitate the procedure Pentothal Sodium is an excellent anesthetic agent for the purpose The surgeon should form a mental picture of the position of the displaced cartilage and then execute the following maneuvers which endeavor to force the displaced meniscus toward the periphery of the joint. The patient assumes the supine position on a firm table and attempts to relax the extremity completely If the medial meniscus of the right knee is involved, the surgeon stands on the outer side and steadies the knee with the left hand and grasps the right ankle firmly with the right hand The limb is then fully flexed, this movement tends to disengage the femoral condyle from the trapped portion of the meniscus Next the inner joint space is opened by abducting the leg this is a very important step in the procedure, and the greatest amount of abduction possible should be attained While this position is maintained, the leg is rotated gently inward and outward When the maximum amount of internal rotation is attained the leg is suddenly but not forcefully extended an audible click often accompanies this last maneuver, indicating that reduction has been achieved For lesions of the lateral meniscus the leg is adducted and in the final extension rotated externally

A free and complete range of painless motion in the knee demonstrated by the patient is the best indication that reduction of the meniscus has been achieved At this point one must note the position of the opposite leg in complete extension It may be possible that a few degrees of hyperextension is normal for the patient therefore 180° extension in the affected limb might not indicate that *full extension* has been achieved and a mechanical block might exist In cases in which replacement of the meniscus has not been accomplished the patient is unable to *attain full extension* actively and passively the examiner encounters an elastic resistance to complete extension. Attempts to extend the leg beyond this point of resistance elicits pain If

it becomes apparent that the meniscus has not been restored to its normal peripheral position, the surgeon must *refrain from the use of force* Forceful attempts to unlock the joint inflict further injury to the damaged meniscus as a rule the longitudinal tear is extended forward into the anterior segment. In addition, forceful extension of the leg in the presence of an anterior intra articular mechanical block stretches the anterior cruciate ligament The surgeon is never justified in allowing weight bearing on a locked knee joint. In such cases *immediate surgical intervention is the treatment of choice* there is no other alternative if irreparable damage to the knee joint is to be avoided

MANAGEMENT OF RECURRENT LESIONS

It has been noted previously that in many instances after the initial injury with or without locking of the joint, the subsequent incidents may exhibit very little tissue reaction, in fact, the patient himself may learn to reduce the displaced meniscus and then continue with his normal activities until the next episode occurs It is interesting to note the number of patients who *have made a mental adjustment to the fact* that they possess a "trick knee" and either voluntarily or because of poor council are of the opinion that nothing can be done medically or surgically for their malady Others labor under the fear that surgical intervention is more likely to accentuate the *disability than to improve it*

Early removal of the offending meniscus is the treatment of choice in all recurrent cases The surgeon must overcome the patient s apprehension and convince him that failure to excise the torn meniscus can lead only to irreparable damage In cases of long *standing with secondary* changes in the supporting elements and the articular surfaces of the joint (osteo-arthritis) the patients must be advised that excision of the meniscus *will lessen the degree of disability* but that the joint will not be restored to normalcy If the patients are advised correctly, they will accept some residual disability *without discrediting* the operative procedure On the other hand, uncomplicated cases of recurrent lesions treated by meniscectomy before irreversible damage is done should achieve restoration of normal function

MANAGEMENT OF TEARS OF BOTH MENISCI

Although tears of both menisci may occur at the original injury this is indeed rare *Generally, the second lesion usually* is a sequel of the instability of the knee joint following the first tear of the meniscus It becomes apparent that when two menisci are involved, some impairment in the supporting structures of the joint exists such as pronounced insufficiency of the quadriceps apparatus and laxity or tears of the ligamentous structure particularly the tibial collateral ligament and the anterior cruciate ligament When there is no doubt as *to the diagnosis of tears of both fibrocartilages* removal of the medial and the lateral structures at a single operation is indicated

Occasionally only one meniscus may be implicated yet its identity may be obscure because of the absence of positive localizing signs. On the other hand it was stressed previously that occasionally lesions of the lateral meniscus may fail to produce symptoms pointing to the lateral compartment of *the joint but instead exhibit clinical manifestations* which erroneously implicate the medial side of the joint Such cases are a challenge to the most acute diagnosticians who often are chagrined when exploration of the joint reveals the true nature of the lesion and fails to confirm the preoperative diagnosis When it is established that one is dealing with an internal derangement of the knee joint and yet the clinical features fail to localize the lesion all the available *clinical data must* be scrutinized carefully then the side of the joint which is most

likely to be implicated is explored, and the meniscus is excised If the structure exhibits a tear, one can assume that it is the offending meniscus, nevertheless, the opposite structure also must be investigated to the extent that an incision on the opposite side of the joint will allow In the event that a normal meniscus is removed, it becomes mandatory that a second incision on the opposite side be made and the remaining meniscus excised

Causes of Poor Results Following Meniscectomy

Faulty Operative Technic. Occasionally meniscectomies performed for simple uncomplicated cases of meniscal tears are followed by a stormy, prolonged convalescence and at times even by some permanent disability Faulty technic employed in the operative procedure may be the responsible factor Too often the operation is attempted by unskilled surgeons who fail to understand the delicate nature of the joint structure, particularly the synovial membrane The author has observed on many occasions the knee joint subjected to brutal trauma tixing force in an attempt to spread the joint space in order to make the meniscus more accessible The synovial membrane is stretched and torn away by such maneuvers predisposing to active bleeding after the joint is closed and the tourniquet is removed. In addition, the collateral ligaments may be stretched and in several instances the tibial collateral ligament actually was severed By using the meniscectomy knife or the scissors blindly in the posterior compartment of the joint the peripheral attachments may be lacerated crudely Such mauling procedures invariably result in severe postoperative tissue reactions and massive hemarthrosis These unfavorable sequelae may lead to a protracted postoperative session and in more severe cases to some permanent impairment of the supportive structures of the joint One case stands out vividly in the author s mind He was called in consultation to see a young man 22 years old on whom a meniscectomy had been performed 3 weeks prior to the visit in question. According to the surgeon who performed the operation, the knee joint became distended markedly immediately after the operation On the following day 150 cc of blood was aspirated from the joint, and a tight compression bandage was applied In spite of this, bleeding recurred, necessitating a second aspiration of blood on the third day Up to the time of the consultation, the joint had been aspirated on 8 different occasions, and notwithstanding continuous compression and the use of ice packs bleeding continued, accompanied by severe pain. Examination of the limb disclosed a distended, boggy knee joint, a 30 flexion deformity and profound wasting of the quadriceps muscle Any attempt to move the joint actively or passively elicited severe pain It was apparent that a large vessel was responsible for the active bleeding and exploration of the joint was recommended The original incision was opened and all free and clotted blood was flushed out of the joint and the suprapatellar pouch. The tibial collateral ligament was found to be severed completely, a ragged laceration of the synovial membrane and the capsule was noted on the inner aspect of the joint in the region of the peripheral attachment of the meniscus and a spurting blood vessel was found in the posterior limb of the laceration behind the posterior margin of the tibial collateral ligament The vessel was clamped and ligated the severed ends of the collateral ligament were approximated with interrupted cotton sutures This case exemplifies the degree of surgical trauma that may be inflicted on a knee joint by surgeons not qualified to perform meniscectomies

Meniscectomies Performed Too Late In neglected cases of long standing the prognosis following meniscectomy must be guarded Not infrequently these cases are complicated by secondary changes which preclude restoration of normal function

after the torn fibrocartilage is removed Repeated episodes over months and years of *giving way and locking of the knee joint* followed by effusion invariably lead to advanced wasting and insufficiency of the quadriceps apparatus, relaxation of the collateral ligaments and even stretching of the anterior cruciate ligament In the presence of the aforementioned sequelae excision of a torn meniscus will result in some improvement of function because the primary *offending agent is removed*, and now the efficiency of the extensor mechanism can be cultivated to *higher levels provided that a* well regulated and intensive postoperative regimen is instituted On the other hand complete return to normality may not be possible in such an event the patient should be informed of the true nature of the situation and must be prepared to accept some *residual* permanent dysfunction of the knee joint This really means that the patient *usually can perform most activities except* those which impose undue strains, particularly rotatory strains on the knee joint.

Occasionally clinical manifestations of a meniscal tear are encountered in joints exhibiting evidence of osteo-arthritis It is *often difficult to decide which lesion is re*sponsible for the disorder In cases with a definite history of a torn meniscus with sub*sequent increasing disability* one must conclude that the meniscal lesion was the irritating factor which is responsible for the development of osteo-arthritis It is true that pathologic processes associated with osteo-arthritis such as erosions and incongruity of the articular surfaces peripheral bony excrescencies *hypertrophied fat pads* and villous synovitis may simulate the clini*cal picture of internal* derangement resulting from meniscal tears Nevertheless when the clinical picture is suggestive of a tear of the meniscus amelioration of the symptoms cannot be anticipated unless the implicated fibrocartilage is removed Even in doubtful cases little harm is done by exploring *the suspected compartment of the knee* joint and removing the meniscus In cases where the symptoms are vague and fail to incriminate the menisci, and clinical studies point to the prevailing osteo-arthritis as the *cause for the symptoms* excision of one or both menisci is not justified More can be gained by simple *conservative measures* designed primarily to improve quadriceps power The author does not wish to convey the thought that menisci never are involved in cases of osteo-arthritis resulting from wear tear and aging The study on degenerative lesions of the knee joint at various *ages reveals that the structures may show* advanced alterations comprising fibrillation shredding and thinning Inasmuch as the knee joints with advanced osteo-arthritis invariably exhibit varying degrees of relaxation of the extensor apparatus the menisci are subjected to repeated minor traumas and in some instances cause severe pain and marked disability *Unfortunately lesions of this nature are encountered most* frequently in obese patients, usually women. They do not always respond to conservative methods In such cases the author does not hesitate to remove the offending structure now redevelopment of quadriceps power *can be commenced and expected to attain such levels that painless function is re*stored However it must be stressed that *after removal of the meniscus* the patient should not expect a normal joint.

Unrecognized Lesions of the Remaining Meniscus. It has been noted previously that occasionally lesions of both menisci are present yet the symptoms may point to only one side of the knee joint Also lesions *of the lateral meniscus may refer* the symptoms to the medial compartment It becomes obvious that a torn meniscus may be left behind or an unaffected meniscus removed In such instances the patients are not relieved of the disorder and the operative procedure falls into disfavor

***Failure to Remove the Meniscus* in Toto** Today as in the past there is considerable controversy relative to the re

moval of the entire meniscus or of only the central portion of a longitudinal tear or only the local excision of pedunculated flaps There is no doubt that the supporters of partial excision of the meniscus attain a high percentage of good results, neverthe less, many poor results following meniscec tomy are the result of failure to remove all of the defective meniscus from the joint. It is common knowledge that many poste rior tears cannot be visualized until the entire meniscus is removed (Figs 91 to 95) Also, more than one longitudinal tear may exist and excision of the one fragment which happens to be displaced into the cen ter of the joint will benefit the patient in no way (Fig 104) If in the course of explora tion of a suspected lesion of the meniscus the posterior peripheral attachments are mobilized it becomes imperative that the entire fibrocartilage be removed, regardless of whether a tear is observed or not Failure to do this predisposes the posterior segment to trappings between the condyles of the femur and the tibia If a lesion is situated in the middle of the meniscus, some sur geons remove only the anterior two thirds of the structure There is no justification for such a procedure, because the remaining posterior segment becomes hypermobile and eventually will be caught between the articular surfaces of the femoral and the tibial condyles.

One must concede that partial removal of a meniscus is a simpler operation than complete removal on the other hand men skilled in the surgery of the knee joint and familiar with the surgical anatomy of the region are capable of excising the fibro-cartilage in toto with minimal surgical trauma. Moreover the postoperative course, the complications and their severity in these cases should not differ from those following partial excision In the light of the obser vations recorded excision of the entire me niscus is the procedure of choice the tech-nic by which this is accomplished rests with the skill and the training of the surgeon

Inadequate Postoperative Management. The surgeon s responsibility does not terminate with the completion of a skill fully performed meniscectomy, for it is his moral obligation to prescribe and supervise a regimen of postoperative management that will restore normal joint function, par ticular attention should be paid to redevel opment of quadriceps power There is no doubt that some failures following menis-cectomy are attributed directly to inade quate treatment after operation or to lack of comprehension of the importance of this phase of the treatment on the part of the surgeon or the patient or both. Neglected cases invariably have a protracted conva lescence, and in some instances the result ing quadriceps weakness causes repeated episodes of giving way and effusions, these sequelae may result in irreparable damage and varying degrees of permanent dysfunc tion of the knee joint.

Coexisting Lesions. Failure to identify coexisting lesions before or during operation may be responsible for poor results in some cases. The lesions most likely to be over looked are hypertrophied fringes of the fat pads, free loose bodies tears or attenuation of the anterior cruciate ligament, tears or sprains of the tibial collateral ligament, chondromalacia of the patella and a lesion of the remaining cartilage.

Operative Management

The successful outcome of meniscectomy depends on many factors it never should be considered as a minor procedure and should be performed by surgeons well versed in the anatomy of the region and possessing a high degree of technical skill In addition the surgeon should be keenly aware of the importance of the preoperative and the postoperative management of the patient Also he should be familiar with the compli cations that may ensue and should be com petent to recognize and treat them

Preoperative Requisites

Too much emphasis cannot be laid on

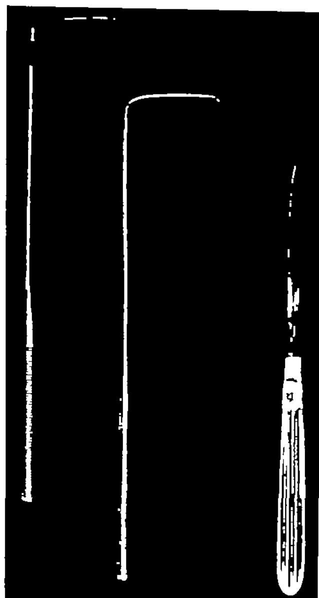


FIG 138 Knife and retractors employed by the author to perform meniscectomies.

the importance of familiarizing the patient with his role in the program. He should be impressed with the fact that in a large measure the success or the failure of the procedure rests on the degree of co-operation that he himself provides and the enthusiasm with which he executes his assignments This is followed by instructing the patient in quadriceps setting and straight leg exercises which should be performed on a regulated schedule for several days prior to operation In order that the patient may master the proper technic of the exercises they should be performed under supervision and the patient should be made to focus his mind on what he is doing This will facilitate resumption of the exercises and preclude disorientation of the quadriceps mass after the operation is performed

Preparation of the local area position of the patient, use of the tourniquet and choice of anesthesia are discussed in Chapter 13, "Surgical Approaches and Procedures"

SPECIAL INSTRUMENTS

Many meniscus knives have been devised from time to time to facilitate removal of the fibrocartilage without undue surgical trauma to the other elements of the joint. The knives most frequently employed are the Lowe Breck knife and the Smillie knives some surgeons use a long thin tenotomy knife The knives devised by Lowe-Breck and Smillie are particularly useful in mobilizing the posterior segment of the meniscus and in severing its peripheral attachments. The author has designed a knife with a long thin, straight blade which is somewhat flexible and is capable of holding a sharp edge (Fig 138) At the end of every operation the knives employed are resharpened and held in readiness for the next meniscectomy

As a rule any narrow thin blade retractor can be utilized to retract the ligamentum mucosum and the collateral ligaments the author prefers those depicted in Figure 138 The Martin meniscus forceps or the Kocher clamp are useful instruments because they grasp the meniscus firmly and permit manipulation of the structure without losing their bite

Skillful execution of meniscectomy does not depend so much on the design of the knife that the surgeon employs as on the dexterity which he acquires with the use of the instrument of his choice This is attained by patience practice and paying attention to all the details of the operation The operation entails a high degree of technical skill The young surgeon should realize this and should strive to achieve it

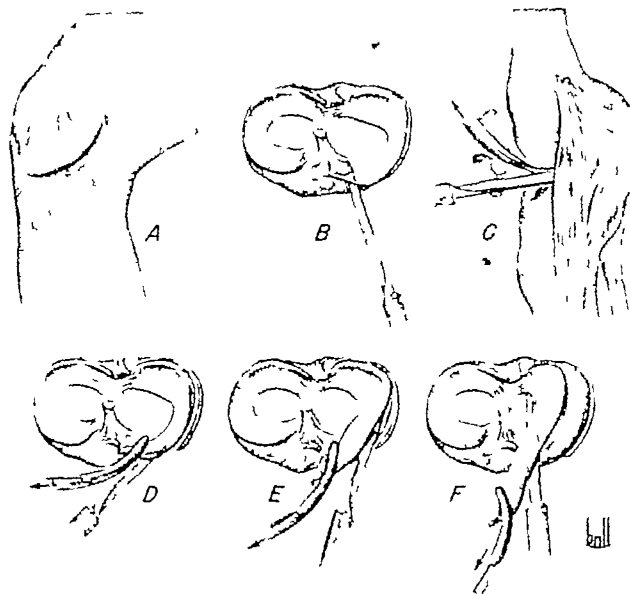


Fig 139 Technic of excising the medial meniscus

INCISIONS

Numerous incisions have been conceived for the removal of the menisci, these are described in detail in Chapter 13, "Surgical Approaches and Procedures For excision of the medial meniscus the author employs a slight modification of the Fisher incision essentially it is an anteromedial curved incision. The advantage of the modification lies in the mild curve of the incision this feature lends itself readily to extension of the incision posteriorly in cases where a second incision in the capsule behind the tibial collateral ligament is needed in order to facilitate removal of the posterior segment of the meniscus

TECHNIC OF MENISCECTOMY

Medial Meniscus (Fig 139) With the patient in the supine position and the knee flexed 90° over the end of the table, the incision begins just above the joint line immediately anterior to the tibial collateral ligament It curves gently downward and forward to the medial margin of the patellar tendon it terminates at a point ½ cm. below the superior border of the tibial condyle The stockinette is clipped to the wound edges with Michel clips With a second scalpel the aponeurosis the capsule and the synovium are incised in the same line of the skin incision Upon opening the joint varying amounts of synovial fluid

will escape immediately In cases of marked joint irritation large quantities of fluid will gush out suddenly and obscure the entire operative field The fluid should be sponged gently with moist gauze the delicate synovial membrane must not be traumatized further by rough handling and coarse dry gauze sponges Next retractors are placed in the wound in such a manner that the wound edges are separated and the infrapatellar fat pad is displaced laterally At this point the joint is examined thoroughly Examination includes inspection of the medial meniscus the articular surface of the femur and the tibia the anterior cruciate ligament, *the anterior tibial spine and the* anterior segment of the lateral meniscus It is practically impossible to examine to any satisfaction the articular surface of the patella and the suprapatellar pouch with the knee flexed at 90 Therefore, the leg is extended to 180 by an assistant The subsequent relaxation of the extensor apparatus allows visualization of the articular surface of the patella also a digital examination of the patella can be made readily *This incision does not afford adequate visualization of the suprapatellar pouch* hence a digital examination must be made of this region.

With the scalpel the anterior segment of the meniscus is mobilized by severing its peripheral attachments to the capsule and the synovium then the blade is placed beneath the meniscus and all its attachments to the tibia are divided under vision The free end of the meniscus is grasped with a Kocher clamp *and a retractor displaces the* tibial collateral ligament inward and backward The thin-bladed meniscectomy knife is placed between the tibia and the under surface of the meniscus and while traction directed toward the center of the joint is maintained on the meniscus its peripheral attachments to the inner surface of the tibial collateral ligament are divided from below upward An assistant now gently but firmly abducts and rotates the leg externally this maneuver tends to open the inner side of the joint space The remaining peripheral tibial attachments of the meniscus are divided by passing the blade in a *horizontal plane along the posterior periphery* of the tibial plateau. At the completion of this step the tibia now is rotated internally and the meniscus is dislocated readily toward the center of the joint its remaining posterior central attachment is divided under direct vision.

As previously noted in rare instances it is impossible to remove the posterior segment of the medial meniscus without undue surgical trauma to other structures This is *true particularly when the ligamentous apparatus* of the joint is unusually tight making access to the posterior regions difficult Also the anteromedial incision may not be adequate to permit removal of a meniscus with advanced cystic degeneration. In such cases the skin incision described above is extended posteriorly and slightly upward to a point 1 cm behind the medial epicondyle of the femur The skin edges are retracted upward and downward *exposing the aponeurosis posterior to the* collateral ligaments and an oblique curved incision is made immediately posterior to the ligament in the aponeurosis the capsule and the synovium It begins immediately below the epicondyle of the femur and continues slightly obliquely downward and forward crossing the joint line This provides excellent exposure of the posterior region of the medial compartment and of the posterior segment of the medial meniscus The *posterior segment of the meniscus* is freed from its peripheral capsular and posterior central attachments by sharp dissection. Now the entire meniscus can be delivered either from the anterior or the posterior incision in the capsule Often the procedure is simplified when the freed anterior half of the meniscus is passed through the posterior incision before the posterior attachments are cut then the entire meniscus is delivered from the posterior opening

The meniscus should be removed by clean *sharp dissection*, tugging, tearing and laceration of the tissues are not necessary and are to be deprecated A final inspection of the joint is made before closure. All free remnants of the articular cartilage, the synovial membrane and the fibrocartilage are removed, invisible fragments in the posterior compartment of the joint are flushed out with a solution of normal saline In order to facilitate closure of the wound the end of the table is raised to the horizontal so that the leg assumes a position of complete extension.

The wound is not closed in layers Closure is achieved by approximation of the aponeurosis the capsule and the synovium by interrupted cotton sutures passing through all layers, interrupted cotton sutures are also used in the subcutaneous tissue and the skin. At the termination of the operation 10 cc. of a solution of penicillin (250 units per cc. of sterile water) is injected directly into the joint cavity This precaution against possible infection has been used routinely in all knee joint operations for the past 5 years

Lateral Meniscus. The lateral meniscus is exposed by an anterolateral incision similar to the incision described above it begins immediately above the joint line and in front of the fibular collateral ligament. It curves gently downward and forward terminating approximately ½ cm below the head of the tibia just lateral to the outer margin of the patellar tendon The aponeurosis, the capsule and the synovium are incised in the level of the skin incision Upon inspecting the inside of the joint one notes that the *anterior horn of the lateral* fibrocartilage occupies a position posterior to that of the anterior horn of the medial meniscus Also with the knee in the flexed position the anterior horn of the lateral meniscus tends to retract these features add to the difficulty of mobilizing the anterior central attachment of the structure After the anterior segment is freed and traction is maintained on it toward the middle of the joint, one observes that the meniscus as a whole moves forward with ease this greatly facilitates its excision making the procedure considerably less difficult than removal of the medial structure. The factors responsible for the relative freedom of the lateral meniscus are the absence of attachment of the convex periphery of the structure to the fibular collateral ligament and the popliteus tendon which is situated between the outer surface of the meniscus and the capsule

If a posterior incision in the joint is necessary, the skin incision is extended posteriorly and slightly upward to a point 1 cm behind and on a level with the lateral epicondyle of the femur The incision in the aponeurosis and the capsule is made parallel with and behind the fibers of the fibular collateral ligament When the capsule is incised the popliteus tendon is visualized anterior to the incision The posterior segment is readily accessible and can be excised by sharp dissection This is a useful incision when large cysts of the meniscus are encountered which cannot be delivered from the anteromedial incision in the joint capsule.

Indications for Opening Both the Anterior and the Posterior Compartments. Although in most instances the meniscus can be excised in toto through an incision anterior to the collateral ligaments occasions are encountered in which an incision in the posterior compartment is necessary in order to facilitate complete removal of the fibrocartilage The joint may be unusually tight so that the removal of the *posterior segment is difficult without the use* of undue forces to open the joint in such cases an incision posterior to the collateral ligament will make the posterior segment readily accessible and should be employed The posterior compartment also should be opened in cases in which the posterior segment has been left behind in a partial meniscectomy Attempts to remove the struc

ture through the anterior opening may result in a transverse rupture at the juncture of the regenerated anterior portion of the meniscus and the remaining posterior portion The reformed meniscus which comprises fibrous tissue may not withstand the amount of traction necessary to dislocate the structure into the center of the joint Also, as pointed out by Smillie, a regenerated meniscus is friable and if its removal is contemplated it is best excised by first mobilizing the anterior portion through an incision in the anterior compartment and then opening the posterior compartment to complete the excision of the posterior segment this precludes rupture of the structure during its removal Large cysts of the menisci may render the delivery of the intact fibrocartilage through an incision in the anterior compartment difficult or impossible here the use of a second posterior incision simplifies the procedure Finally when loose bodies in the posterior compartment are associated lesions of a meniscal tear they are made readily accessible by an incision in the joint capsule posterior to the collateral ligament

Treatment of Cysts of the Menisci Once cystic degeneration of the menisci has progressed to the size that symptoms are produced the treatment of choice is surgical excision of the entire meniscus together with the concomitant lesion Conservative measures are futile. In cases of small lesions of either the medial or the lateral meniscus the operative procedure is similar to that of excision of the fibrocartilage However large cysts may demand a modification of the technic As noted previously an incision in both the anterior and the posterior compartments simplifies the operation

Cysts of the medial meniscus may reach large proportions and project posteriorly as far as the popliteal space In such instances a second incision made in the posterior compartment is necessary in order to identify the limits of the cystic mass and to remove it in toto together with the meniscus Now the mass can be readily dissected free from the inner side of the capsule under vision. In the event that the cyst has penetrated the tibial collateral ligament the anterior and the posterior portions of the affected meniscus together with the cystic mass first are mobilized, then the exit of the mass through the capsule and the ligament is widened by two small vertical incisions one above and one below the point of exit the extruded mass now can be made to retrace its steps and is delivered with the meniscus either through the anterior or the posterior incision in the capsule

Large cystic masses of the lateral meniscus together with the fibrocartilage are removed best by the use of an anterior and a posterior capsular incision The posterior incision is of particular value in disclosing the relationship of the cysts to the fibular collateral ligament and the tendon of the popliteus muscle also through it the cysts and the posterior segment of the fibrocartilage are mobilized readily and dissected free from all surrounding tissue under vision

Important Technical Points in Meniscectomy Failure to pay strict attention to every detail of the operation, step by step may result in much confusion on the part of the surgeon and severe trauma to the delicate tissues of the knee joint.

Adequate exposure of the meniscus is the first requisite of the operation This can be achieved only by an accurately placed incision As noted previously many incisions have been designed to provide the desired exposure However too often the incision chosen is not placed correctly it may be too high or too low in relation to the joint line too far anteriorly or too far posteriorly The edges of such improperly placed incisions often are stretched severely by the surgeon in an effort to obtain the desired exposure Incisions crossing the course of the infrapatellar nerve may cut this structure If possible this should be avoided by identifying the nerve and retracting it out of harm s way However division of the

nerve is not a serious technical error, it rarely results in unfavorable sequelae After the deep fascia of the leg is divided the capsule and the synovium should be picked up between 2 forceps before they are opened, in order to avoid injury to the joint structure The incision in the capsule and the synovium is made in the line of the skin and the fascial incision, on the medial side it begins just in front of the tibial collateral ligament about ½ cm above the superior margin of the meniscus and continues to the inner margin of the patellar tendon. Then the synovial and the capsular attachment of the anterior segment of the meniscus are visualized

Large hypertrophied fat pads may obscure the anterior central attachment of the meniscus. If it is not possible to obtain adequate exposure by lateral displacement of the fat pad it may be necessary to cut away a portion of this structure Large severed vessels in the fat pad should be ligated

When the middle third of the meniscus is freed from its peripheral attachment, the true plane between the inner surface of the capsule and the convex periphery of the meniscus must be identified and the thin bladed knife should be passed between the two structures under vision this is achieved readily by making traction on the freed anterior segment in the dissection of the center of the joint Careful execution of these steps precludes division of the tibial collateral ligament or cutting through the convex periphery of the meniscus Blind cutting of the attachments of the middle third may result in partial division of the segment this weakens the structure so that moderate traction may tear it from the posterior segment If this complication occurs, the posterior third may retract deeply in the posterior compartment making its removal exceedingly difficult If the posterior segment is not readily accessible a second incision in the posterior compartment facilitates its removal

In most instances after the thin blade is passed along the posterior periphery of the tibial plateau, the posterior segment is mobilized sufficiently to allow the entire meniscus to be dislocated into the intercondylar notch, now the remaining capsular and the posterior central attachments can be divided under vision Occasionally, in tight joints or in cases of a meniscus with normal posterior capsular attachments, it may be difficult to displace the meniscus as a whole into the center of the joint. As previously noted in these cases forceful brutal manipulation should be avoided instead the posterior segment should be freed through an incision in the posterior portion of the capsule as described above.

IMMEDIATE POSTOPERATIVE MANAGEMENT

At the close of the operation before the tourniquet is removed, 2 or 3 layers of cotton are wrapped around the knee extending from mid thigh to 6 inches below the knee. This is compressed around the joint by a 3 inch elastic bandage extending from the toes to the middle of the thigh, making uniform, snug compression. The author does not employ a posterior gutter splint. Now the tourniquet is removed, it is a safe policy for the surgeon to assume the responsibility of this procedure When the patient is transferred to his bed the limb is elevated on hard pillows in a position of extension and ice bags are placed on both sides of the knee joint. Compression is maintained for 7 or 8 days, the sutures are removed on the ninth or the tenth postoperative day

Restoration of Normal Function

Following surgical procedures on the knee in which the continuity of the extensor mechanism is not interrupted the methods employed to restore joint function and normal muscular development are essentially the same However, they are tempered by the duration and the severity of the lesion prior to surgical intervention and by the individual peculiarities of the patient Also the intensity of the program must be gov

erned by the tolerance of the patient strenuous or prolonged exercises may over tax the quadriceps muscle resulting in varying degrees of effusion and pain In general quadriceps setting exercises are commenced on the second day and should be executed under supervision 2 or 3 times daily for 15 to 20 minutes in addition, the patient should practice forceful contraction of the muscle every hour for 5 minutes As soon as the patient has mastered the quadriceps drill straight leg exercises without resistances are added as a rule this may be achieved on the third or the fourth day Occasionally patients are encountered who have great difficulty in performing the straight leg exercises these individuals require special attention and coaching The author has found that straight leg exercises performed against the resistance of a rubber tubing as depicted in Figure 203 rapidly restores power and volume in the quadriceps he prefers this form of exercises to loaded straight leg raising using sand bags and weights By adding additional pieces of tubing the resistance against straight leg raising is increased progressively Like the quadriceps drill the straight leg raising exercise is performed on a regulated schedule for 5 minutes every hour This program is continued for 10 days during this period no weight bearing is allowed However some flexion exercises of the knee joint may be performed within the confines of the compression bandage

At the end of 10 days the compression bandage is removed and if no effusion exists and the quadriceps shows good power weight bearing is permitted In the presence of an effusion or a weak quadriceps or both no weight bearing is allowed During the next week knee flexion exercises in addition to straight leg exercises against resistance are continued weight bearing during this phase of the treatment is kept to a minimum and frequent rest periods are prescribed Long periods of standing walking or performing occupational may cause an effusion which may retard the progress of the recovery As a rule by the third week the quadriceps muscle is ready to start resistance exercises as described in Chapter 7 These develop power and volume in the extensor apparatus which in turn stabilizes the knee joint and protects the ligamentous apparatus against repeated strains Once power is restored exercises such as stair-climbing cycling and the use of pulleys can be employed to develop endurance.

It is of utmost importance to study and evaluate correctly the tolerance of the individual patient Some patients progress more slowly than others and if in the former the muscles are worked beyond their capacity recurrent effusion ensues and may influence the ultimate recovery seriously or even may produce irreparable damage to the knee joint.

Normal restoration of function is achieved in from 10 to 12 weeks At the end of this period most patients are capable of resuming normal activities this applies also to those engaged in strenuous athletics or laborious occupations Individuals doing light or sedentary work may return to their employment as early as the fourth or the fifth week after operation Patients receiving compensation for a knee injury may not adhere to the timetable recorded above In spite of the absence of objective findings some of these individuals may register pain limitation of motion and stiffness in the knee joint It has been noted frequently that these vague symptoms rapidly disappear after a monetary settlement satisfactory to the patient has been made

Postoperative Complications

One or more of the complications about to be discussed may occur even when meniscectomy is performed by the most adroit surgeon However their incidence and severity is increased the operation is executed by the when the surgeon fails to pay tention to all the de

tails of the procedure In general, unfavorable sequelae tend to prolong convalescence and in some instances are responsible for irreparable and permanent damage to the joint.

HEMARTHROSIS

Active bleeding into the joint cavity is usually the result of failure to look for and ligate large vessels during the course of the operation Often large vessels pierce the infrapatellar fat pad When this structure is incised, these vessels can be seen readily if one takes time to investigate the area They should be picked up and tied A common source of bleeding is division of the inferior lateral geniculate artery when the lateral meniscus is removed The close proximity of this vessel to the periphery of the capsular attachment of the fibrocartilage makes it unusually vulnerable to surgical trauma. In addition failure to apply a snug compression bandage around the knee prior to removal of the tourniquet may result in troublesome hemorrhage into the joint, and too early mobilization of the joint may be responsible for postoperative bleeding

The clinical features depend upon the amount of blood in the joint cavity and the reaction of the patient Small hemorrhages may give rise to minimal local and systemic reactions and little discomfort on the other hand more extensive hemorrhages may produce pronounced reactions and symptoms of great intensity In the latter cases the patient has intense acute pain which differs from the sense of fullness and distention incident to an effusion On palpation the joint tissues exhibit a rubbery resistance and firm pressure elicits acute tenderness. The local temperature is increased and the patient discloses evidence of a systemic reaction manifested by a rise in temperature and an increase in the leukocyte count

Blood in the joint cavity is an irritant to the synovial membrane failure to remove this agent by the normal channels principally the lymphatics, results in thickening of the synovialis, organization of the blood clots and eventually formation of adhesions Massive hemorrhages cause increased intra-articular pressure which in turn collapses the lymphatic channels hence, there is interference with the normal process of removing the blood cells from the joint cavity In the light of these observations it becomes imperative that hemarthrosis be recognized early and that the joint be decompressed by repeated aspirations This should be followed by the application of a tight elastic compression, and the joint should be placed at complete rest until the danger of recurrence of the bleeding has passed, this entails a period of 1 to 2 weeks At the end of this period the regimen to restore quadriceps power and joint function is instituted Hemarthrosis invariably prolongs the period of convalescence and recurrent hemorrhages may result in irreversible joint changes implicating chiefly the synovialis and the extensor mechanism of the joint

POSTOPERATIVE EFFUSION OF TRAUMATIC ORIGIN

Small amounts of synovial effusions following meniscectomy are encountered frequently The volume is usually greater in recent meniscal lesions than in old lesions in which varying degrees of relaxation of the capsule and the ligaments have occurred thereby making the excision of the meniscus a relatively simple procedure As a rule in skillfully performed operations the resulting small effusion is not a serious sequela and readily disappears when the extensor apparatus regains good power and adequately stabilizes the joint and protects it from harmful strains Large massive effusions evident shortly after the operation are generally the result of excessive surgical trauma undue manipulation of the joint and much prolonged stretching of the soft tissues This complication is observed frequently in cases where the surgeon insists on excising the meniscus through a small

buttonhole incision and severely stretches *the wound edges in order to expose the* structure in addition, he is forced to work blindly in the joint No one can dispute that in a large measure large persistent post operative effusions can be prevented by handling the tissue gently and by manipulating the joint sparingly Fortunately in the advent of large effusions resulting from the aforementioned causes, no serious consequences ensue, provided that the post operative management of the lesions is adequate In these cases weight-bearing must not be permitted until quadriceps exercises have *restored sufficient tone and power to* the extensor apparatus to protect the soft tissue elements from further injury incident to weight bearing Under such a program the effusion will subside gradually but return to normalcy is definitely prolonged

Exercises designed to strengthen the quadriceps muscle never must exceed the capacity of the muscle strenuous or prolonged exercises cause fatigue which in turn predisposes the joint structures to harmful strains because the protective action of the quadriceps is diminished or lost Persistent effusion is a frequent concomitant finding in these cases This is also true in cases in which unrestricted weight bearing is permitted before the quadriceps has regained sufficient power to protect the joint from strains incident to weight bearing

EFFUSION OF INFECTIOUS ORIGIN

Occasionally persistent effusion is observed in patients *who also exhibit signs* of a local inflammatory process and a systemic reaction comprising low grade fever leukocytosis and increased sedimentation rate Often the clinical picture is interpreted erroneously as a postoperative reaction Instead this is a low grade sepsis of the joint the postoperative use of antibiotics directly into the joint and administered parenterally *is responsible for the confusing clinical picture* The author has observed 3 such cases the knee joints are swollen exhibit increased local temperature and on palpation *disclose more* resistance than would be encountered in a simple effusion This feature is produced by capsular thickening and a hyperplasia of the synovial membrane Aspiration of the joint reveals a turbid synovial fluid with a high cellular count Culture of this fluid fails to reveal the presence of organism undoubtedly, the antibiotics are responsible for the negative cultures. Repeated aspirations and complete immobilization of the limb does not prevent further recurrence of the effusion The author's cases responded favorably to the following *treatment The limb was put at complete* rest by adhesive traction supplied to the lower leg making a pull not greater than 5 pounds continuous hot packs were applied to the joint. The joint cavity was aspirated every second or third day, and following each aspiration 500 000 units of penicillin in 10 cc. of sterile water was injected into the joint In addition 300 000 units of penicillin was administered parenterally twice daily At the end of 2 weeks the local and the systemic reactions had disappeared then quadriceps exercises were instituted to restore the limb to normalcy Smith has reported similar cases in which he employed fever therapy induced by the use of typhoid vaccine this measure was used in combination with the administration of antibiotics

SEPSIS

Improved methods and technics of aseptic surgery have rendered true sepsis with frank pus in the joint cavity a rare complication of meniscectomy the recent advent of chemotherapy and antibiotic agents has played a major role in reducing the incidence of this tragic sequel Frank sepsis has not occurred in any of the author's cases but several cases were seen in consultation. When such a complication occurs it is usually indicative of a break in the aseptic *technic or may be caused by* reactivation of a focus of infection elsewhere in the body

This complication exhibits both general

and local manifestations The patient becomes toxic and shows evidence of dehydration, the pulse is rapid, and the temperature is septic in character, occasionally, the patient may have repeated chills followed by a rapid elevation of the temperature Blood studies reveal a high leukocytosis and a rapid sedimentation rate Local signs are always present, pain is severe, and the knee is held in a position of flexion muscle spasm is a constant clinical feature, and the joint is swollen and exhibits increased local temperature. The slightest active or passive motion elicits severe pain In the early stages roentgenologic studies fail to show any evidence of cartilage or osseous involvement except some slight demineralization of the bones. However, the joint space may be widened and the capsule distended Negative roentgenograms at this stage are of no clinical significance

Management of a septic knee should strive to control the infection without resorting to open drainage of the knee joint However, every effort should be made to evacuate the joint cavity of the pus which causes rapid lysis of the articular cartilage Free drainage not only renders the joint vulnerable to secondary organisms but also deprives the joint of the benefit of the bactericidal affect of the synovial fluid It is important to identify the organism responsible for the infection, hence the joint should be aspirated immediately a smear and a culture of the fluid should be obtained and the susceptibility of the organisms to the different antibiotic agents determined

At the completion of the first aspiration 500 000 units of penicillin in 10 cc. of sterile water is injected into the joint cavity This is performed daily In addition 300 000 units is administered intramuscularly twice daily and 1 Gm of sulfadiazine is given by mouth twice daily The entire limb is placed at complete rest by adhesive traction applied to the lower leg to which from 3 to 5 pounds of weight are suspended Continuous hot fomentations to the joint during the day provide considerable comfort to the patient If the patient is very septic, small transfusions of whole blood (250 cc.) given every 3 or 4 days will reduce the toxicity and improve the general health and the resistance of the patient A close watch must be maintained on the patient's fluid and electrolyte balance, and appropriate intravenous fluids should be administered as required. The aforementioned regimen is continued until all evidence of constitutional and local manifestations of the infection has disappeared The patient is now ready to undertake the task of restoring optimum function in the limb In these patients the convalescence may be protracted and rehabilitation progresses slowly

POSTOPERATIVE PAIN

Although some discomfort in the operative area is present, severe pain is not a common complaint Pain minimal in intensity may be felt when the patient first attempts to initiate quadriceps drill and straight leg raising However, this diminishes rapidly in severity Traction of the quadriceps apparatus on the incision is responsible for this pain However, severe pain immediately or several days after the operation may occur this may be the result of one or a combination of several factors

Immediate Postoperative Pain In most instances this complication invariably follows severe surgical trauma to the soft tissues during the course of the operative procedure Undue traction on and stretching of the synovialis the capsule and the skin margins is the chief cause Also forceful manipulation of the joint and severe rotatory strains inflicted on the ligamentous apparatus while trying to attain adequate exposure of the posterior regions of the joint will result in acute postoperative pain in most cases Massive postoperative effusions usually demonstrable from 24 to 48 hours after the operation are frequently concomi

tant findings of such unnecessary surgical trauma

Occasionally an elastic compression bandage applied too tightly may cause intense pain Usually this is associated with varying degrees of swelling of the limb distal to the bandage In those instances rapid removal and reapplication of the elastic bandage plus elevation of the extremity suffice to relieve the acute pain

Failure to attain complete hemostasis may result in massive hemorrhage into the joint which as previously noted always is associated with persistent pain The diagnosis and the management of this sequela have been discussed previously

Late Postoperative Pain. The most common cause for the onset of persistent intense pain several days following the operative procedure is the accumulation of a large volume of blood in the joint cavity This may result from injudicious forms of exercises, too early weight bearing before *the quadriceps is sufficiently strong to stabilize* the knee joint or latent active bleeding resulting from inadequate hemostasis As previously recorded, another cause of latent pain is sepsis which may be in the nature of a low grade inflammatory process accompanied by persistent effusion or true suppuration of the joint these forms are associated with systemic reactions of varying severity

Painful Scar The incidence of persistent painful scars following excision of the medial meniscus is exceedingly low However varying degrees of hypersensitivity of the scar for several months after operation is now an infrequent occurrence Generally in these cases the degree of sensitivity diminishes progressively and after 3 or 4 *months it disappears completely* The disorder is undoubtedly the result of irritation of the severed ends of the infrapatellar plexus which are caught in the scar and are *irritated by stretching of the scar* or by the clothing during motion In 2 cases this feature became so annoying that the patients *demanded some form of intervention* Both responded to minimal doses of irradiation to the sensitive scar

Much has been recorded in the literature relative to the formation of neuromata following division of the main trunk of the infrapatellar nerve In fact, many incisions were designed purposely to avoid division of the nerve Clinical experience reveals that painful neuromata following operative procedures on the medial aspect of the knee are exceedingly rare In the author s series only 2 cases developed a persistent painful area *in the region of the operative area following* excision of a medial meniscus In one a small tender mass the size of a pea was palpable immediately below the line of the incision this proved to be a true neuroma arising from the proximal end of the severed infrapatellar nerve In the second case a mass also about the size of a pea was palpable 1 cm proximal to the line of the incision *The lesion was excised and microscopic* study disclosed its true nature It was a glomus tumor In the event that a painful neuroma is encountered, the lesion should be excised, together with a portion of the nerve from which it arises this removes the severed end of the nerve from the line of the skin incision.

A more common complaint than pain in *the region of the scar is anesthesia distal to* the line of incision The size of the anesthetic area is governed by the number of branches of the infrapatellar nerve which have been divided If the main trunk has not been severed the area is relatively small division of the main branch results in larger areas of anesthesia Fortunately in most cases the anesthesia is not permanent the *rich overlap of sensory* fibers of the infrapatellar plexus in this region ensures restoration of normal sensation Permanent anesthesia occurs only in the exceptionally rare cases and in these it generally is of no significance

PHLEBOTHROMBOSIS AND THROMBOPHLEBITIS

The incidence of these lesions following meniscectomy is exceedingly rare, nevertheless, 4 cases were encountered in the author's series Early active exercises of the affected limbs after operation is a major prophylactic factor and is responsible for the infrequent occurrence of the disorders In the 4 cases of this series the patients were all over 40 years old (47 52, 56 and 58 respectively), the disorder was ushered in with pain and swelling in the calf muscles In 2 cases tenderness along the course of the internal saphenous vein in the thigh was demonstrable In all the temperature rose slightly above normal All cases responded favorably to antibiotic and anticoagulant therapy Also the extremities were elevated and wrapped in voluminous hot packs quadriceps drill was performed every hour within the packs Within 3 to 4 days the tenderness and the swelling diminished substantially and the temperature returned to normal levels at the end of this period the patients were put on the usual program of exercises to restore normal quadriceps power and joint function None of these cases required blocking of the lumbar sympathetic ganglia with procaine however this method has been employed in thrombophlebitis subsequent to operative procedures elsewhere in the body (particularly following operations on the hip joint in elderly people) and has been found to be a valuable adjunct in relieving pain and muscle spasm and in enhancing resolution of the thrombus

DEGENERATIVE LESIONS OF THE MENISCI

It was pointed out in Chapter 6 "Disorders of the Extensor Apparatus of the Knee Joint that the menisci like other elements of the knee joint exhibit degenerative changes resulting from wear tear and senescence These abnormalities increase in gradient in each successive decade, however, the changes are in most instances compatible with normal function. The alterations comprise loss of elasticity, fraying and wrinkling of the inner free margins and narrowing of the peripheral attached margins. Advanced abnormalities comprise thinning and fasciculation of the menisci, some fibrocartilages even exhibit plaques of calcareous material grossly within their substance or on the surfaces

Occasionally, degenerated menisci give rise to symptoms and signs of internal derangement of the knee joint, this is particularly true when mechanical disorders of the joint exist such as genu valgum and genu varum Such disorders subject the menisci readily to abnormal stresses which tend to increase the intensity of the degenerative changes In addition many of these patients are obese with poor quadriceps tone and relaxation of the capsular and the ligamentous structures The degree of insufficiency of the extensor mechanism plays a large role in the severity of symptoms nevertheless the meniscus per se tends to impede recovery In addition to a sense of instability in the knee joint pain is a pertinent clinical manifestation it is usually localized on the side of the affected meniscus and pressure over the peripheral attachments of this structure invariably elicits acute tenderness

Conservative treatment should be employed as the method of choice in all these cases these comprise physical measures such as radiant heat gentle massage and a regulated program of heavy resistance exercises designed to increase the power of the quadriceps muscle If such measures fail one is justified in removing the implicated meniscus. The author has observed several cases in which after the meniscus was removed the aforementioned palliative measures effected marked improvement in the stability of the joint and alleviated the pain

It is true that many cases disclose vary

ing degrees of osteoarthritis which may be responsible in a measure for the pain and the dysfunction However this is no contra indication to the plan of treatment outlined above provided that the signs and the symptoms point to the meniscus as the most responsible offender Moreover the presence of a degenerated fibrocartilage which is capable of producing severe disability tends to increase the progression of the osteoarthritic process, and therefore its removal is justifiable

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6

Disorders of the Extensor Apparatus of the Knee Joint

CONGENITAL MALFORMATIONS

Congenital anomalies of the extensor apparatus are not encountered frequently they may implicate the muscular and the tendinous portion of the extensor mechanism the patella or both The alterations may impede normal function of the knee joint and in some instances lead to severe disability A rare congenital alteration is malformation of the quadriceps group of muscles some or all of its elements may be underdeveloped or even absent (Fig 140) the vastus medialis is especially prone to exhibit these abnormalities Of the components of the extensor apparatus the patella exhibits the greatest number of malformations Occasionally it occupies an abnormally high position in the quadriceps tendon or it may be displaced laterally for varying distances (Fig 141) The insertion of the patellar tendon may be on the lateral surface of the tibia instead of on the tibial tubercle Various forms of contractures of the soft tissue elements of the knee may occur Notably among these are the contractures of the extensor apparatus, causing an extension deformity of the knee as in congenital genu recurvatum and contractures of the flexor of the knee These soft tissue contractures will be discussed more fully in



Fig 140 Extensor mechanism of the knee joint with congenital absence of the vastus medialis

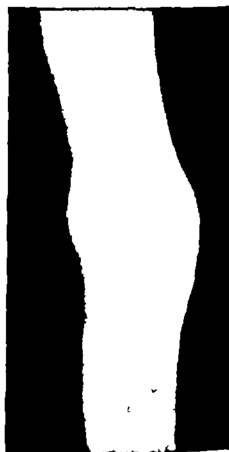


Fig 141 Congenital anomaly of the patella It occupies a position on the lateral aspect of the knee joint In this case the insertion of the patellar tendon is on the lateral surface of the tibia.

Chapter 7, "Congenital and Acquired Deformities of the Knee Joint."

Congenital Abnormalities of the Patella

As noted above, numerous and varied congenital deformities of the patella have been observed The patella may be absent Although rare, this may be a hereditary characteristic, absence of the patella has been recorded in association with multiple arthrodysplasia F A Stuart brought to the author's attention a case of congenital absence of the patellae in a male 16 years of age, the knee joints are capable of normal function. The patient's mother also has congenital absence of the patella she lacks 50° of extension in each knee (Fig 142 A and B) The patella may be underdeveloped, it may occupy an abnormally high position in



Fig 142 (*Top*) Bilateral congenital absence of the patellae in a boy 16 years old. This patient can perform complete extension (*Bottom*) The mother of this boy She lacks 50° extension in each knee. (From Dr Frank A Stuart, Tulsa, Okla)

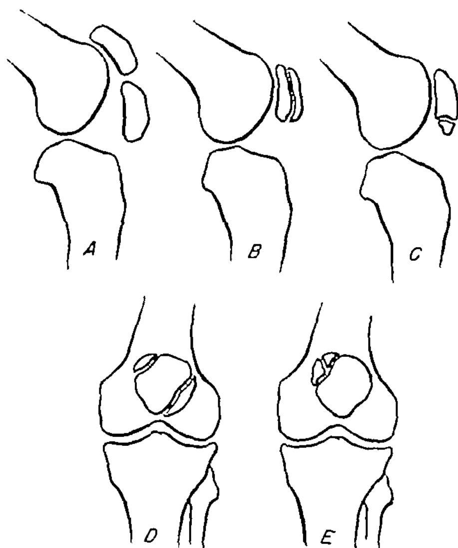


FIG 143 Types of anomalies of the patella (A) Haenisch, (B) Petty



FIG 144 Bipartite left patella in a boy 12 years old the right patella is normal

ne quadriceps tendon, or it may be dis-laced laterally for varying distances. In the atter instance, there may coexist an abnor nality of the patellar tendon which may be nchored to the lateral aspect of the tibia Relatively common developmental altera ions are bipartite and tripartite patella, he smaller fragments are usually situated n superolateral region of the patella but all ragments may be approximately the same ize Frequently, these lesions are inter reted erroneously as a fracture of the pa ella, particularly when the part was sub-ected to trauma prior to roentgenographic tudy Haenisch described a bilateral double atella in which one bony element was an erior to the other, the former being the arger and possessing a concave posterior urface which articulated with the anterior urface of the smaller bone (Fig 143) Petty as recorded a case possessing a bilateral ouble patella an interval of ½ to 1 inch xisted between the two bones, suggesting evelopment and ossification from two nu lei (Figs 143 and 144)

RECURRENT DISLOCATION OF PATELLA

General Considerations

The etiologic factors responsible for this disorder may be congenital or acquired Superficial survey of a group of 54 cases disclosed that trauma was the initiating agent for the subsequent recurring disloca tions in 32 of the cases (This series does not include dislocated patellae following transplantation of the biceps femoris ten don into the patella in cases of paralysis of the quadriceps group) However more criti cal assessment of this group revealed that in 24 cases some form of congenital ab-normality of the extensor apparatus existed, predisposing the extremity to the condition In 5 of the remaining cases no abnormalities were discernible indicating that trauma alone was the responsible factor for the dis-order in 3 cases acquired genu valgum deformity was the underlying predisposing factor In the remaining one third of the cases the congenital alterations per se were



Fig 145 Pronounced relaxation of the extensor apparatus (bilateral) permitting marked lateral displacement of the patella

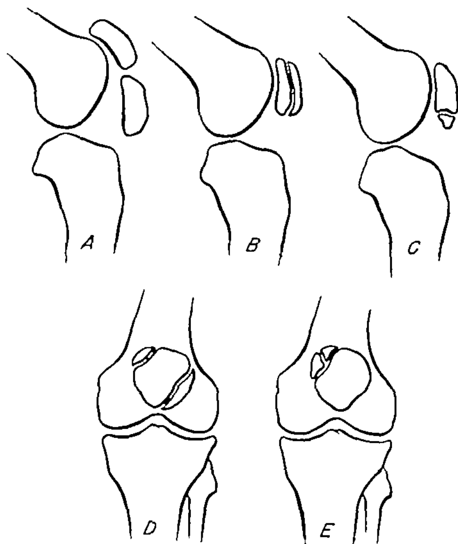


Fig 143 Types of anomalies of the patella. (A) Haenisch, (B) Petty

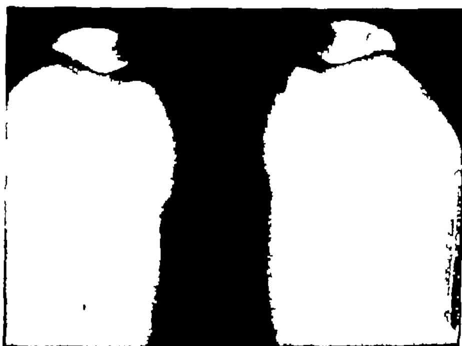


Fig 144 Bipartite left patella in a boy 12 years old the right patella is normal

the quadriceps tendon, or it may be displaced laterally for varying distances In the latter instance, there may coexist an abnormality of the patellar tendon which may be anchored to the lateral aspect of the tibia Relatively common developmental alterations are bipartite and tripartite patella the smaller fragments are usually situated in superolateral region of the patella, but all fragments may be approximately the same size Frequently, these lesions are interpreted erroneously as a fracture of the patella, particularly when the part was subjected to trauma prior to roentgenographic study Haenisch described a bilateral double patella in which one bony element was anterior to the other the former being the larger and possessing a concave posterior surface which articulated with the anterior surface of the smaller bone (Fig 143) Petty has recorded a case possessing a bilateral double patella an interval of ½ to 1 inch existed between the two bones suggesting development and ossification from two nuclei (Figs 143 and 144)

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The etiologic factors responsible for this disorder may be congenital or acquired Superficial survey of a group of 54 cases disclosed that trauma was the initiating agent for the subsequent recurring dislocations in 32 of the cases (This series does not include dislocated patellae following transplantation of the biceps femoris tendon into the patella in cases of paralysis of the quadriceps group) However more critical assessment of this group revealed that in 24 cases some form of congenital abnormality of the extensor apparatus existed, predisposing the extremity to the condition. In 5 of the remaining cases no abnormalities were discernible, indicating that trauma alone was the responsible factor for the disorder in 3 cases acquired genu valgum deformity was the underlying predisposing factor In the remaining one third of the cases the congenital alterations per se were



Fig 145 Pronounced relaxation of the extensor apparatus (bilateral) permitting marked lateral displacement of the patella

of sufficient severity to permit recurrent dislocations without trauma as a major role in the onset of the condition The most frequently encountered congenital abnormality was congenital relaxation of the extensor apparatus of the knee joint (Fig 145) In their order of frequency the other alterations were congenital genu valgum, maldevelopment of the lateral condyle of the femur or deficient intercondylar sulcus (Fig 146) anomalies of the patella as underdevelopment and lateral displacement of the patella (this was invariably associated with some abnormality of the quadriceps muscle particularly underdevelopment of the vastus medialis) outward torsion deformities of the upper end of the tibia (in these instances the ligamentum patellae is displaced laterally) and the presence of abnormal fascial bands extending from the posterolateral border of the patella to the iliotibial band and the intramuscular septum anterior to the biceps tendon This abnormality was found in 4 cases the lesion was first described by Ober (1935)

As noted above trauma may be the sole causative agent for recurrent dislocation of the patella. In this group trauma results in excessive tearing and shredding of the medial patellar retinaculum and avulsion of the fibers of insertion of the vastus medialis into the upper and inner aspect of the patella Faulty repair of the soft tissue structures disturbs the normal mechanics of the extensor apparatus leading to recurrent or even persistent dislocation of the patella It was pointed out in Chapter 4, "Mechanics of the Knee Joint" that the vastus medialis plays a major role in the stability of the patella Normal attachment of this muscle to the superomedial aspect of the patella together with an intact medial patellar retinaculum good tone of the extensor muscular apparatus and an adequate intercondylar sulcus are the principal factors stabilizing the patella during normal movements of the knee joint The normal knee joint exhibits about 10 to 12° of natural lateral deviation This is an essential feature of the knee joint because the medial femoral condyle projects distally to a slightly lower level than the lateral hence, in order that both condyles may lie in a true transverse plane when the patient assumes the erect position



Fig 146 Figure on left shows underdevelopment of the lateral femoral condyle allowing dislocation of the patella compare with the opposite knee on the right

and the knee is extended fully, the tibia is deflected slightly outward at the knee joint It becomes apparent that with such an arrangement the vertical axes of the quadriceps muscle and the patellar tendon do not coincide, the latter deviates downward and outward, forming an obtuse angle with the former at the level of the patella In order to prevent lateral displacement of the patella the vastus medialis pulls the bone upward and medially thus opposing the vastus lateralis which pulls obliquely upward and laterally According to Duchenne the medialis and the lateralis are antagonists in lateral motion of the patella and synergists in extension of the knee In the presence of minor congenital deviations of these stabilizing features trauma is capable of precipitating recurrent dislocation of the patella

In this series there are 4 cases of persistent dislocation of the patella, 2 being bilateral (e.g., Case G S, Fig 147) and 2 unilateral Thirty six patients were females and 18 were males the right knee was involved in 29 cases and the left in 25

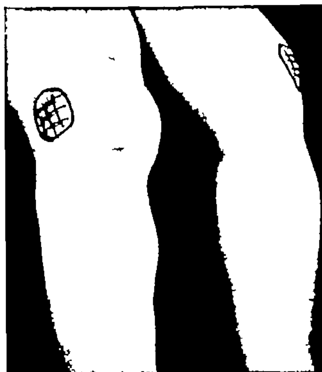


Fig 147 Case C S Bilateral persistent dislocation of the patellae This patient has pronounced dysfunction and advanced secondary osteoarthritic changes in both knee joints

Clinical Manifestations

Symptoms

In general, the cases of recurrent dislocation of the patella can be grouped into two categories (1) no clinical evidence of dysfunction of the knee joint existed until some form of injury occurs, or (2) symptoms of weakness and instability exist without a history of trauma In the latter group if an injury occurred the symptoms were accentuated Also, the intensity of the symptoms varies In general, they are at first mild in nature the patient is aware of a sense of weakness and insecurity in the affected joint. The knee tends to buckle and the patella slips over the margin of the lateral condyle. Each instance of subluxation usually is associated with swelling resulting from synovial effusion into the articular cavity Later the subluxation is replaced by a true dislocation of the patella With each episode there is pain and tenderness particularly on the medial aspect of the joint the patient walks with a limp As a rule the displacement is reduced readily by simple extension of the knee on occasion manual reduction is necessary Frequently, the patients are very vague concerning the actual mechanism of the disorder and emphasize the sense of insecurity the giving way of the joint and the pain on the anterior and the inner aspects of the knee It becomes obvious that these manifestations may lead one to make an erroneous diagnosis of internal derangement implicating the internal meniscus This is true especially in cases of subluxating patella With dislocation the symptoms are greatly intensified being caught off guard, the patient often falls down when the incident occurs

The group in which the disorder is initiated by trauma offers fewer difficulties in arriving at a correct diagnosis. In many instances the initial dislocation fails to re

of sufficient severity to permit recurrent dislocations without trauma as a major role in the onset of the condition The most frequently encountered congenital abnormality was congenital relaxation of the extensor apparatus of the knee joint (Fig 145) in their order of frequency the other alterations were congenital genu valgum maldevelopment of the lateral condyle of the femur or deficient intercondylar sulcus (*Fig* 146) anomalies of the patella as underdevelopment and lateral displacement of the patella (this was invariably associated with some abnormality of the quadriceps muscle particularly underdevelopment of the vastus medialis), outward torsion deformities of the upper end of the tibia (in these instances the ligamentum patellae is displaced laterally) and the presence of abnormal fascial bands extending from the posterolateral border of the patella to the iliotibial band and the intramuscular septum anterior to the biceps tendon This abnormality was found in 4 cases the lesion was first described by Ober (1935)

As noted above trauma may be the sole causative agent for recurrent dislocation of the patella. In this group trauma results in excessive tearing and shredding of the medial patellar retinaculum and avulsion of the fibers of insertion of the vastus medialis into the upper and inner aspect of the patella Faulty repair of the soft tissue structures disturbs the normal mechanics of the extensor apparatus leading to recurrent or even persistent dislocation of the patella It was pointed out in Chapter 4 "Mechanics of the Knee Joint" that the vastus medialis plays a major role in the stability of the patella Normal attachment of this muscle to the superomedial aspect of the patella, together with an intact medial patellar retinaculum good tone of the extensor muscular apparatus and an adequate intercondylar sulcus are the principal factors stabilizing the patella during normal movements of the knee joint. The normal knee joint exhibits about 10 to 12° of natural lateral deviation This is an essential feature of the knee joint because the medial femoral condyle projects distally to a slightly lower level than the lateral hence, in order that both condyles may lie in a true transverse plane when the patient assumes the erect position



FIG 146 Figure on left shows underdevelopment of the lateral femoral condyle allowing dislocation of the patella compare with the opposite knee on the right

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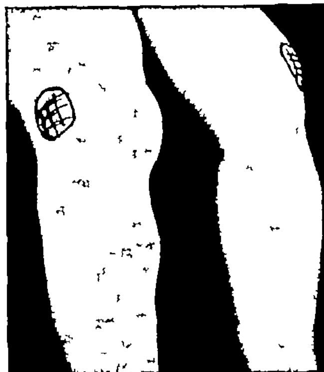


FIG 147 Case C S Bilateral persistent dislocation of the patellae This patient has pronounced dysfunction and advanced secondary osteoarthritic changes in both knee joints.

CLINICAL MANIFESTATIONS

SYMPTOMS

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Fig 148 (*Top*) Traumatic dislocation of the patella requiring manual reduction. (*Bottom*) Same knee after reduction. Note the extent of swelling of the knee joint.



Fig 149 Demonstrates the amount of lateral instability of the joint in a case of recurrent dislocation of the patella of long standing.

duce spontaneously requiring manual reduction (Fig 148) pain is acute swelling is pronounced and dysfunction is marked Following the initial dislocation the clinical course is similar to that described for the nontraumatic group

Physical Findings. A constant finding in all cases of recurrent dislocation of the patella is varying degrees of laxity of all the components of the extensor apparatus and the medial portion of the capsular tissues The vastus medialis exhibits profound loss of volume this is noted to a lesser degree in the remaining elements of the quadriceps muscle In addition lateral hypermobility of the patella exists this can be demonstrated readily by pushing the bone outward In some instances when this maneuver is performed forcefully a dislocation results Moreover frequently the patient tends to check the force employed by the examining hand because of the fear that a dislocation will ensue If the examination is performed shortly after an episode of dislocation some effusion may be demonstrable in the joint and tenderness is elicited when pressure is made along the anteromedial aspect of the joint.

Frequently the patella which may be underdeveloped rides high on the anterior surface of the femur and is displaced laterally the displacement is increased by flexion of the knee This is true particularly when the prominence of the lateral condyle is diminished or when increased deviation of the knee is present Many cases disclose some lateral instability of the joint arising from generalized relaxation of all the soft

tissue elements about the joint, including the collateral and the capsular ligaments (Fig. 149) Depending upon the duration of the symptoms and the severity of the lesion, some diminution in the range of flexion and extension of the joint may exist. Motion often is associated with varying degrees of crepitation in the patellofemoral joint. Old cases exhibit clinical manifestations consistent with osteoarthritis, such as irregularities of the patellar margins, thickening of the capsular and the pericapsular tissues, loud coarse crepitus and marked dysfunction of the knee joint (e g , Case G S , Fig 150)

Roentgenologic Features. With the knee in the extended position, any increase in the deviation of the knee joint is readily discernible The patella may appear malformed and occupies a higher position than the opposite bone, it may be displaced laterally for varying distances Upon flexion of the knee the undeveloped lateral condyle of the femur is demonstrable and the patella may shift still further on the lateral aspect of the femur (Fig 151) Concomitant cartilaginous and osseous lesions may be visualized these include chondromalacia of the articular surface of the patella, osteochondritis of the femoral condyles congenital abnormalities of the patella (such as bipartite and tripartite patella), loose bodies (synovial osteochondromatosis) and osteoarthritic changes of all the cartilaginous and the bony elements of the joint (Fig 150)

Associated Lesions

Occasionally, other lesions coexist with recurrent dislocation of the patella. In the author's series there were 6 males with lesions of the internal meniscus, 4 of these exhibited a longitudinal tear in the middle and anterior thirds of the meniscus, and 2 disclosed advanced shredding of the under surface of the posterior third In 5 cases the lesions were suspected before definitive surgery for the dislocating patella was performed, and in 1 the lesion was overlooked,



Fig 150 Case of old persistent bilateral dislocated patellae Note the the extensive osteo-arthritic changes in both knee joints.



Fig 151 Note how the patella shifts laterally on the underdeveloped femoral condyle when the knee is flexed

necessitating a second operation It is common knowledge that degenerative changes of varying severity in the articular cartilage of the lateral femoral condyle and the patella are inevitable sequelae of this disorder (Fig 150) In cases of long standing the alterations reach profound proportions characterized by areas of complete destruction of the cartilage and eburnation of the underlying bone Two cases showed a large osteochondritic area in the medial femoral condyle It was interesting to note that one of these also revealed a tear of the internal meniscus Advanced synovial osteochondromatosis was observed in one case Varying degrees of synovitis were noted in the majority of the cases, and in 3 cases of long duration villonodular synovitis with advanced osteoarthritic alterations was present. As previously recorded abnormal fascial bands such as described by Ober were encountered in 4 cases

Treatment

The numerous operations designed to cure this malady are a good indication that no single procedure succeeds in all cases Most of the operations succeed in stabilizing the patella in the majority of cases however it is the small percentage of failures which is most disconcerting both to the surgeon and the patient In general the technics most commonly employed tend (1) to change the line of pull of the quadriceps apparatus from a lateral to a more medial position (Goldthwait and Hauser) (2) to maintain the patella in the intercondylar sulcus (Gallie) (3) to restore the depth of the intercondylar sulcus by elevating the prominence of the

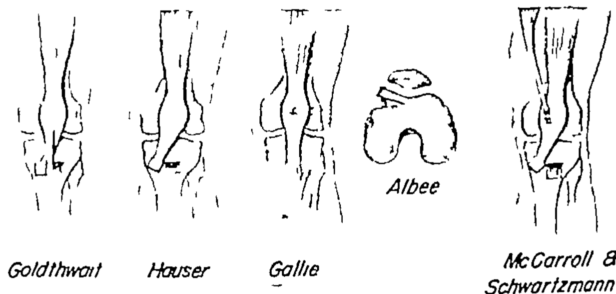


Fig 152 Types of operations to stabilize the patella in recurrent dislocation

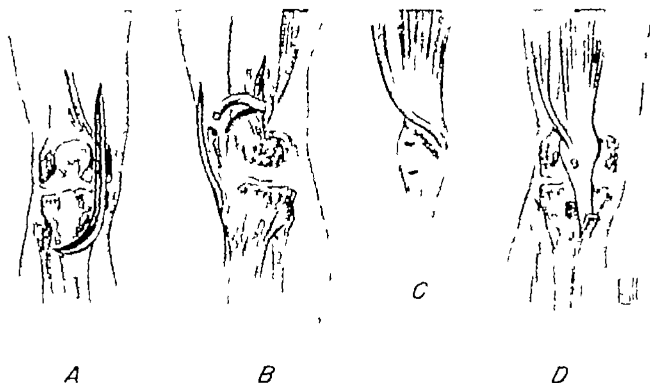


FIG 153 Method of McCarroll and Schwartzman (modified), utilized in children

lateral condyle of the femur (Albee) and (4) to correct the laxity of the soft tissues on the medial aspect of the joint by doing a plastic operation on the capsule and the medial patellar retinaculum (this includes reefing or plicating the affected tissues) (Fig. 152) The author has employed all of these procedures and has come to the conclusion that although they are adequate in most instances none remedies the disorder in all cases Since 1945 the technic described by McCarroll and Schwartzmann slightly modified has been used routinely in all cases no recurrences have occurred in this group Essentially this operation comprises transplantation of the semitendinosus to the patella and transference of the tibial tubercle to the medial surface of the tibia at a slightly lower level than its original site By this method the patella is maintained in the medial position of the extremity by a firm attachment above and below preventing any shift of the bone to a lateral position. Recently the author has modified this procedure slightly in adults by employing the method of anchorage of the tibial tubercle recommended by Smillie and utilizing a lateral incision shaped like a hockey stick

OPERATIVE TECHNIC
(McCarroll and Schwartzmann)

Two incisions are made the first is a lateral incision shaped like a hockey stick, beginning slightly above the base of the patella and extending directly downward to just below the tibial tubercle (Fig 153 A) It then curves medially and distally for 2 inches By reflecting the skin flaps the tendinous insertion of the sartorius muscle comes into view, this is divided in the line of its fibers exposing the tendons of the gracilis and the semitendinosus muscles The tendon of the semitendinosus is identified (it lies inferior to the tendon of the gracilis) and isolated by sharp dissection from all attachments then it is divided close to its point of insertion into the tibia

Next the hip and the knee are flexed the limb is rotated externally and the second incision is made It is 2 inches in length and begins at the mid point of the thigh

along its posteromedial aspect (Fig 153 B) The muscle mass of the semitendinous is identified as it lies along the posterior aspect of the semimembranosus muscle Its identity is facilitated by making traction on its detached tendon. The muscle is isolated by blunt dissection and by gentle traction upward together with its tendon it is drawn through the incision

With a long Kelly clamp a subcutaneous tunnel is created extending downward and forward from the second incision to the proximal limit of the first incision The tunnel should be sufficiently wide to allow free excursion of the muscle belly and its tendon. After the tendon of the semitendinosus is drawn through the tunnel the second incision is closed

In growing children detachment of the tibial tubercle must be executed carefully in order to prevent injury to the epiphyseal line of the tibia This is achieved readily by using a thin blade osteotome which is placed *beneath the tendon and parallel with the* long axis of the leg and by removing only the superficial layer of bone of the tibial tubercle to which the patellar tendon is attached (a block of bone is not removed) The tendon then is brought forward and dissected free from the underlying extra synovial fat it is mobilized further by splitting the lateral patellar retinaculum from below upward along the lateral edge of the vastus lateralis This line of division extends proximally to that level which allows the patella to assume a mid line position on the anterior surface of the femur

The tibial tubercle with the attached patellar tendon is drawn distally and medially generally it can be displaced approximately 1½ inches below the level of its original anchorage By splitting the fibers of the sartorius expansion in this region the underlying periosteum is exposed on the periosteum the upper limit and the two sides of the new anchorage of the tibial tubercle are outlined with a scalpel Then in children a thick osteoperiosteal flap is elevated from above downward, leaving in tact the bone and the *periosteum at the base* of the flap (Fig 153 D) Several small drill holes are made in the flap and through these are passed sutures of stout silk or wire anchoring firmly the tibial tubercle to the posterior surface of the flap After the transference of the tibial tubercle is accomplished the patellar tendon should make firm but not undue tension on the extensor apparatus to maintain the patella in the desired medial position In addition fixation of the patellar tendon is enhanced by attaching it to the adjacent periosteum and the expansion of the sartorius by interrupted sutures

Now the patella is made ready to receive the tendon of the semitendinosus By using a small osteotome a vertical tunnel is made from above downward through the body of the patella (Fig 153 C) care must be taken not to disturb the new attachment of the tibial tubercle The semitendinosus tendon is drawn through the tunnel and while mod*erate tension is maintained it is anchored to* the quadriceps tendon and the patellar tendon by interrupted sutures The gap in the lateral patellar retinaculum is left open and the edges of the subcutaneous tissue and the skin are approximated with interrupted sutures A plaster cast is applied extending from the toes to the groin holding the limb in the extended position at the knee joint At the end of 4 weeks this is replaced by a skintight plaster cylinder reaching from above the malleoli to the upper region of the thigh At this time progressive quadriceps exercises are instituted and weight bearing is permitted After 4 weeks the cylinder is removed and physical measures such as gentle heat massage and flexion and extension exercises are added in order to obtain optimum restoration of function at the knee joint

As previously recorded the author employs Smillie s method to anchor the tibial tubercle in adults This eliminates the possibility of displacement of the tibial tubercle and permits weight bearing at the end of 2

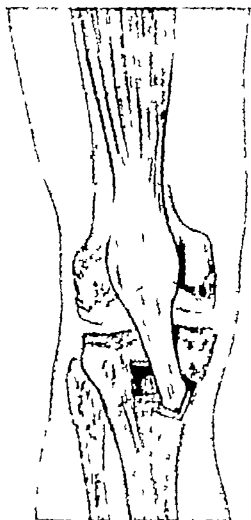
weeks and flexion at the knee joint at the end of 4 to 5 weeks

OPERATIVE TECHNIC (*Smillie*)

The tibial tubercle and the attached patellar tendon are exposed in a manner similar to that described above a rectangle of cortical bone with the tendon attached measuring 1¼ in by ½ in. is removed with a sharp thin osteotome (Fig 154 A) The long axis of the rectangle lies in the vertical plane. A defect corresponding in size to the cortical bone removed is outlined and made on the anteromedial aspect of the tibia at a lower level (1 to 1½ in) than its orig inal site of attachment its long axis is inclined inward so that it makes an angle of 45° with the vertical axis of the tibia. With a curet the cancellous bone is removed from beneath the cortical bone at the superior and the inferior ends of the defect. Next the tibial tubercle is placed in the defect and driven below the level of the cortical bone then it is rotated so that it is locked in position and its vertical axis coincides with that of the quadriceps (Fig 154 B)

After the semitendinosus is transplanted and the wound closed a posterior moulded plaster splint is applied, extending from the toes to the upper region of the thigh At the end of 2 weeks the wound is in spected, and the skin sutures are removed The limb is then encased in a skintight plaster cylinder extending from 2 inches above the malleoli to the upper region of the thigh weight bearing is now permitted, and quadriceps exercises are commenced All fixation is removed at the end of 2 or 3 more weeks and active measures are in stituted, designed to restore quadriceps

FIG 154 (A *Left*) Method of Smillie employed to anchor the tibial tubercle in adults. (B, *Right*) Roentgenogram showing the tibial tubercle in its new bed on the medial aspect of the tibia





volume power and normal motion at the knee joint

NONOPERATIVE TREATMENT

Certain cases of recurrent dislocation exhibit no congenital abnormalities except increased laxity of the soft tissues and poor tone of the quadriceps muscle Other cases disclose only minor congenital defects which with the added factor of trauma may develop the disorder Such cases should be given a trial of conservative management designed to reduce tissue laxity and increase muscle tone particularly that of the vastus medialis This goal can be achieved only by a carefully supervised regimen of quadriceps exercises as described on page 260 In the event that this form of therapy fails surgical intervention is justified

PERSISTENT DISLOCATION OF PATELLA

This lesion may be congenital in nature or may be the sequela of recurrent dislocation congenital or traumatic in origin I author s series there were 4 cases of sistent lateral dislocation of the pate were bilateral and 2 unilateral One c bilateral cases was an elderly woman (G S) whose mother also had persisten location of the patellae (Fig 150) unilateral case was a young man wh tained the initial dislocation while pl football a direct blow was delivered t inner side of the kneecap A general thesia was necessary to reduce the di tion the limb was then placed in a pl cast for 3 weeks This was followed feeling of insecurity in the affected joint and several episodes of recurren location which the patient reduced hi by extending the knee joint Finally patella assumed a fixed position on lateral aspect of the knee and did not medially any appreciable distance on e sion of the knee (Fig 155)

Persistent dislocation of the patella be partial or complete often it is assoc



Fig 155 (*Left*) Case S S with persistent dislocation of the patella following trauma sustained in football (*Right*) Roentgenogram shows the fixed lateral position of the patella

with other congenital deformities of the knee particularly genu valgum On occasion, with the knee flexed the lateral displacement of the patella is so great that the quadriceps follows it the lower end of the femur is readily palpable under the skin In many instances the function of the joint is relatively good, but as the patient increases in age severe dysfunction may occur resulting from secondary degenerative changes in the joint (Fig 156)

Treatment

Essentially, the surgical approach to this problem is similar to that of recurrent dislocation of the patella. The patella may be bound firmly in its abnormal position by fibrous bands extending from its lateral border to the fascia lata and the undersurface of the iliotibial band. Ober has described such bands, believing that in recurrent dislocation there was an abnormal relationship between the patella and the iliotibial band He also described a fibrous band extending from the patella to the intramuscular septum at the anterior aspect of the biceps tendon

The author is convinced that patellectomy has no place in the surgical treatment of recurrent or persistent dislocation of the patella However, in the presence of severe osteoarthritic changes characterized by pronounced incongruity of the patellofemoral articular surfaces and hypertrophic bone formation patellectomy may be the only surgical procedure which will afford some comfort to the patient and improve function of the knee In Case G S (Fig 150) the disability in both knee joints was severe The patient had constant pain and swelling was becoming progressively worse She was barely able to stand extension was possible to 135°, and quadriceps power was poor Exploration of the joints revealed that the patellae were bound firmly to the lateral aspects of the knees by dense firm bands extending to the iliotibial bands The articular cartilage of the patellae, the femurs and the tibiae exhibited profound degenerative changes (Fig 156) A diffuse villonodular synovitis was present in both joints In addition to patellectomy synovectomy was done After 4 months of physical therapy and quadriceps exercises the patient was able to extend the knees to 165°, she had some discomfort but no intense pain and was able to do her housework something that had not been possible for many years

PRIMARY DISLOCATION OF PATELLA

Initial lateral displacement of the patella resulting from congenital alterations in the



Fig 156 Undersurface of patellae obtained from a case of persistent dislocation. Note the pronounced degeneration of the articular cartilage and the peripheral excrescencies.

structures responsible for the stability of the patella has been discussed previously However complete or incomplete dislocation also may occur in normal knees or in knees exhibiting only minor abnormalities when direct force is applied to the inner aspect of the patella driving the bone laterally Severe direct force to the lateral or the superior aspects of the patella may drive the bone to a medial or an inferior position such lesions are exceedingly rare A rarer lesion is rotation of the patella on its longitudinal axis for varying degrees Cases of complete rotation have been recorded The author has encountered one such dislocation which was irreducible by closed manipulative measures it required open operation to restore the bone to its anatomic position The lesion is encountered usually in young people who are engaged in strenuous activities such as football or basketball It becomes obvious that in the young muscular individuals in whom no anomalies of the quadriceps mechanism exist who possess well-developed stabilizing structures great force must be expended to displace the patella from its normal anatomic position Depending upon the degree of dislocation varying intensities of damage are inflicted upon the extensor apparatus particularly the medial patellar retinaculum the medial portion of the fibrous and the synovial capsule and the vastus medialis Occasionally tangential osteochondral fracture of the patella results

In incomplete dislocations the patella rides the lateral prominence of the lateral femoral condyle In such instances soft tissue injury usually is not severe The medial parapatellar structures may be stretched and even frayed but as a rule remain intact Injury to the synovialis may be followed by an effusion or a hemarthrosis Some of the fibers of the vastus medialis may be frayed or torn from their attachment to the superomedial margin of the patella. Generally the dislocation is reduced spontaneously when the knee is extended On occasion the patient or someone else pushes the bone into place

Examination of a reduced incomplete dislocation discloses no evidence of the nature of the disorder Besides swelling the other pertinent clinical manifestation is pain on pressure over the superomedial border of the patella and over the medial aspect of the knee In the absence of any visible abnormalities of the knee one is apt to interpret these findings as the result of a torn internal meniscus The diagnosis is made readily in unreduced cases the knee is held slightly flexed, and the patella is seen and felt riding on the lateral margin of the lateral femoral condyle

Complete dislocations are associated with more extensive soft tissue damage the patella comes to lie at the lateral aspect of the lateral femoral condyle Generally the pathology comprises rupture of the medial parapatellar retinaculum and the medial portion of the fibrous capsule and its synovial lining and avulsion of the muscle fibers of the vastus medialis from their line of insertion into the superomedial margin of the patella With disruption of the aforementioned structures blood and synovial effusion which, with an intact capsule normally would accumulate in the joint cavity issue forth into the overlying soft tissues All tissues in this region become edematous being infiltrated with blood and synovium this feature in many instances precludes recognition of a tear in the capsule and the medial parapatellar structures by inspection and palpation of the part Moreover powerful extension of the knee joint is still possible because the lateral portion of the extensor mechanism together with the iliotibial band is able to perform this function It becomes apparent that a diagnosis of the severity of the injury is difficult to determine especially when spontaneous reduction has occurred Some workers suggest injection of air into the joint capsule the presence of air in the soft tissues points to a rent in the capsular tissues

Treatment

Proper evaluation of each case is the key note to successful management of this disorder The pertinent points to consider are (1) the degree of displacement of the patella this knowledge provides a clue to the severity of damage sustained by the medial portion of the quadriceps mechanism and the capsular tissues, (2) a history of previous dislocations and (3) in cases of complete dislocations, the true nature of the pathology present in the soft tissues and the presence or the absence of injury to the articular surface of the patella (osteochondral fracture)

As previously noted many cases reduce spontaneously If the displacement is present at the time of the initial examination, reduction usually is achieved readily by extension of the knee and pushing the patella medially over the lateral prominence of the lateral femoral condyle, the patella then assumes its normal anatomic position on the anterior surface of the femur The manipulation should be executed with the patient under a general anesthesia. Subsequent treatment is governed by the evaluation previously made of each case Those which have a history of previous dislocations are treated in accordance with the methods discussed in the section, Recurrent Dislocations of Patella (p 193) The management of all incomplete and complete primary dislocations should aim to restore a powerful quadriceps apparatus and to prevent recurrent dislocations

In incomplete lesions the above goal is attained by aspiration of blood and synovial fluid from the joint cavity and application of a compression bandage At this time no weight bearing is permitted If fluid continues to accumulate evacuation of the joint cavity may be repeated several times every 2 or 3 days Usually within 7 to 10 days the joint approaches normalcy at this time a skintight plaster cylinder is applied, extending from 2 inches above the malleoli to the upper region of the thigh with the knee in the extended position Weight bearing is allowed also, progressive quadriceps exercises are commenced The patient must be made aware of the importance of the exercises and encouraged to perform them on a regulated schedule It may be necessary to reapply the plaster cylinder after 2 or 3 weeks because it may become too large and does not fit the leg snugly After a period of 5 to 6 weeks the cast is removed, and exercises to restore flexion of the joint are added to the regimen, the quadriceps exercises are intensified

The aims in the management of complete dislocations of the patella are similar to those of incomplete lesions In most instances conservative treatment is the method of choice and does not differ from that outlined for incomplete dislocations This line of treatment is justified by the observation that in the event of rupture of the medial patellar retinaculum and the medial capsule, and even of avulsion of the fibers of the vastus medialis retraction of these structures does not occur sufficiently to preclude good repair by simple fixation of the limb in extension Retraction is prevented by the intact lateral and anterior portions of quadriceps mechanism and the intact lateral capsular tissues In cases exhibiting extensive disruption of the medial capsule and the medial patellar retinaculum, surgical intervention should be employed The region is exposed readily by a median parapatellar incision, the medial capsule and the fibrous expansion of the vastus medialis are approximated in layers by interrupted cotton sutures On several occasions the author has encountered severe disruption of the affected tissues, making a suitable repair impossible by simple suturing of the tissues in layers, a wide strip of fascia lata, obtained from the same limb was employed to strengthen the repair After completion of the operation the limb is placed in a plaster cylinder Subsequent management is similar to that described for incomplete dislocations of the patella.

IRREDUCIBLE LATERAL DISLOCATION OF PATELLA WITH ROTATION

Lateral dislocation of the patella with rotation about its long axis is rare how ever several cases have been reported in the literature The earliest report was made by Cooper in 1844 Sanborn recorded a case in 1856 Borchard reported another in 1901 and Brown one in 1902 More recently, Trausner Orsos and Martin each reported a case The last case on record was reported by Inman and Smart in 1941 Some of the cases were reduced by forceful manipulation under anesthesia others defied all closed methods requiring surgical intervention to achieve reduction In those cases that were explored surgically except in the case of Martin severe tearing of the capsular tissues and the medial quadriceps expansion was encountered invariably The patella rotates on its long axis so that the medial edge impinges and locks under the border *of the lateral femoral condyle* Its articular surface faces outward and downward The mechanism of the dislocation is a severe driving force applied to the medial side of the patella which forces the bone laterally while the knee is in almost complete exten sion and the quadriceps taut Recently the author has encountered a case of lateral dislocation of the patella with rotation which was impossible to reduce by manipu lation Reduction was achieved by surgical intervention

Case Report

G C., a male 19 years old was admitted to the Jefferson Medical College Hospital on June 6 1952 While playing baseball he was kicked on the inner aspect of the right knee he experienced severe pain and fell to the ground At the initial examination of the pa tient a large prominence was visible and palpable on the lateral aspect of the knee which was extended approximately 170 The



Fig 157 Irreducible traumatic lateral dislocation of the patella in a male (C 19 years old also a small avulsion fracture of the tibial tubercle is present

bony prominence, which obviously was the patella, lay in an oblique plane approaching the sagittal plane Its medial margin had dipped beneath the lateral border of the femoral condyle while its articular surface faced obliquely downward and outward The patellar tendon had shifted laterally and was taut like a bowstring In spite of the severity of the deformity there was no clinical evidence of a synovial effusion or hemarthrosis Pressure over the medial side of the joint elicited marked tenderness, the intercondylar sulcus of the femur was palpable under the stretched skin Roentgenographic study, including tangential roentgenograms, disclosed the true nature of the displacement (Fig 157) In addition a small avulsion fracture of the tibial tubercle was discernible

The patient was given a general anesthesia using Pentothal Sodium Three attempts were made to manipulate and lever the patella into its normal position, all failed. On the following day the region was explored through an anterior mid line incision Upon reflecting the skin margins, the extensive soft tissue damage on the medial aspect of the knee was visualized All tissues were friable and infiltrated with blood and synovial fluid The vastus medialis was torn from its patellar attachment and a large irregular longitudinal tear traversed the medial patellar retinaculum from above downward close to the medial border of the patella and extended into the substance of the lower muscle fibers of the vastus medialis The patella was found rotated on its long axis approximately 85 with its articular surface facing downward and outward It was interesting to note the twist in the quadriceps and the patellar tendons in which its medial fibers were rotated to an inferior position and its lateral fibers to a superior position. The tendon of the patella was unduly taut helping to maintain the displacement of the bone.

Reduction was achieved readily by dislodging the medial border of the patella from under the lateral margin of the lateral femoral condyle and slipping it over the condyle Derotation of the patella the quadriceps and the patellar tendons followed the patella then assumed its anatomic position on the anterior surface of the femur

Repair was effected by reattaching the vastus medialis to the superomedial border of the patella. The muscle was anchored to the edge of the bone by stout cotton mattress sutures approximating the torn muscle and to the fascial and the periosteal layers of the patella The medial patellar retinaculum and the fibrous capsule were closed in layers. The limb was placed in a plaster cylinder, extending from above the malleoli to the upper region of the thigh with the knee extended At the end of 2 weeks quadriceps exercises were started, after 1 more week weight bearing was permitted. The cast was removed at the end of 6 weeks A recent follow up examination 6 months after the injury disclosed good quadriceps power a normal range of motion and no instability of the knee Slight atrophy of the vastus medialis was still demonstrable Redislocation had not occurred

RUPTURES OF THE EXTENSOR APPARATUS

These lesions may be grouped into two categories (1) those encountered in the older age groups and (2) those occurring in young adults usually actively engaged in strenuous athletics In the first category the most important lesions are rupture or avulsion from the patella of the tendon of the quadriceps femoris muscle, and in the second, avulsion of the patellar tendon from the tibial tubercle occasionally, a piece of the tubercle is avulsed from the shaft. Also, the patellar tendon may be avulsed from the inferior pole of the patella, and groups of fibers of the vasti muscles may be ruptured (these may be minor or extensive lesions) Immediate recognition of the nature of the pathology following an injury is imperative because excellent results are obtained by early surgical repair, in late cases restoration of the continuity of the quadriceps apparatus is difficult and complicated and the results are often far from satisfactory both to the surgeon and the patient

FRESH RUPTURE OR AVULSION OF QUADRICEPS MUSCLE FROM PATELLA

As noted previously, this lesion usually occurs in individuals beyond the fourth decade, who are often overweight. However

the author has observed the disorder in a thin woman 34 years old this case was of special interest because a second avulsion of the same quadriceps occurred 18 months after the first. Essentially the mechanism of the injury is violent contraction of the quadriceps muscle with the knee partially flexed A common history is stumbling while descending steps or a curb In order to regain balance the patient momentarily braces himself forcefully contracting the quadriceps of the extremity which support the full weight often he hears a snap or a crackling in the region of the knee followed by severe pain and loss of balance He then falls suddenly to the ground

Pathologic Findings

Generally, a transverse tear is found in the quadriceps tendon, traversing its entire thickness so that the suprapatellar pouch comes into view In recent cases the pouch is full of blood serum and blood tinged synovial fluid The tear only on rare occasions is limited to the tendons of the rectus femoris and the vastus intermedius muscles Generally it extends laterally and medially implicating the fibrous expansions of the vastus lateralis and medialis for varying distances The tissues are infiltrated with blood and the margins of the tear are often ragged periosteal tabs may be found attached to the base of the patella In other instances the tendon is avulsed from its insertion on the patella

Clinical Manifestations

The diagnosis is made readily provided that correct interpretation is given to the clinical features Frequently the true nature of the lesion is overlooked because the examiner does not suspect the possibility of a rupture of the quadriceps tendon and depends too heavily on roentgenographic findings which usually are negative As noted previously the cardinal clinical features are a history of stumbling in patients past middle age who experience severe pain above the knee and inability to extend the knee joint *Examination of the part reveals* a transverse sulcus just above the patella which is best demonstrated by palpation it becomes more apparent when the patient contracts the quadriceps Depending on the duration of the lesion varying discolorations of the skin about the joint are discernible Occasionally the ecchymosis is severe and extends for varying distances below the level of the knee Pressure over the anterior and lateral aspects of the joint elicits tenderness Contraction of the quadriceps fails to extend the leg at the knee In rare cases in which only the tendon of the rectus femoris muscle is implicated and the medial and the lateral patellar retinaculum are intact extension of the leg is possible In such instances the diagnosis often is missed and may not become apparent for several months until the patient fails to achieve normal power in the quadriceps and a calcifying hematoma becomes demonstrable in roentgenograms Swelling of the knee is never a prominent feature because the blood and the synovial fluid escape into the surrounding soft tissues.

Treatment

Repair of the defect should be achieved by surgical intervention in all degrees of tears Even those cases in which active extension of the leg is possible, indicating that the lesion is limited to the tendon of the rectus femoris muscle the patient is assured of an extremity approaching normalcy only if the two ends of the tendon are approximated by sutures If possible the operation should be performed within 24 hours however, primary union may be attained in cases from 4 to 5 weeks old

Tendon-to-Tendon Repair

A L shaped incision affords adequate exposure of the region moreover this incision can be projected upward readily on the lateral aspect of the thigh in those cases needing reinforcement with fascia lata The

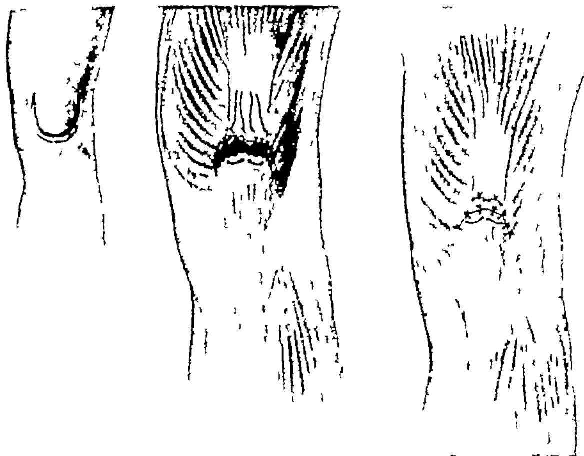


Fig 158 Tendon to-tendon repair

Fig 159 A strip of fascia lata may be employed to re-enforce the suture line.

skin and the deep fascia are reflected upward exposing the extensor mechanism All clots are removed from the suprapatellar pouch and the cavity is flushed with a solution of normal saline Then the extent of the tear is determined and the edges of the tendon are trimmed of all devitalized and frayed strands of tissue A towel clip is placed on the proximal end of the tendon, which now is drawn distally until it is in apposition to the distal end While traction is being maintained on the towel clip the two ends of the tendon are joined by two mattress sutures of braided silk or kangaroo tendon. The tears in the medial and the lateral expansions of the tendon are closed with interrupted cotton sutures Some workers employ strips of fascia lata for the mattress sutures although this is excellent suture material it is not essential in most cases (Fig 158) Occasionally, the author has reinforced the suture line with a wide strip of fascia lata obtained from the same side This is done only in those instances in which the ends of the tendon are very friable and the disruption of the tissues is severe The reinforcing strip is sutured to the vasti muscles above and to the patella and it medial and lateral retinaculum below (Fig 159 A to D)

TENDON TO-BONE REPAIR

The technic differs slightly in cases of avulsion of the tendon from its attachment to the base of the patella The end of the tendon is approximated to the bone by a mattress suture of braided silk passing through two drill holes in the body of the patella and tied on its anterior surface (Fig. 160) Beginning at the base of the patella two drill holes are made in the longitudinal axis of the bone, they are directed downward and slightly anteriorly so that the drill points emerge on the anterior surface of the lower portion of the patella Tears in the lateral expansions of the vastus medialis and lateralis are repaired in the manner described above

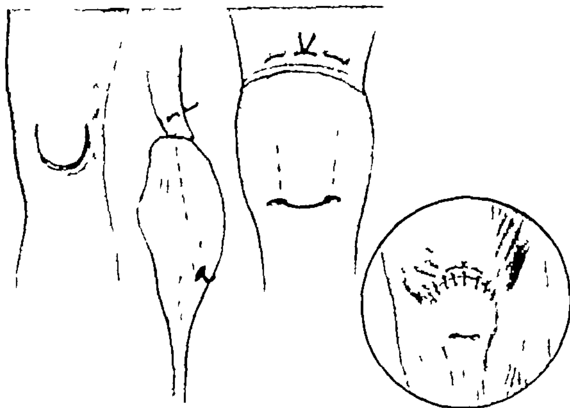


Fig 160 Tendon to-bone repair

Postoperative management is similar to that described for old ruptures of the quadriceps tendon

OLD RUPTURES OF THE QUADRICEPS TENDON

Neglected cases exhibit marked disability because of the total lack of stability in the affected extremity Many of these patients must depend on the use of a cane or a brace in order to walk The quadriceps muscle becomes shortened, and thin friable strands of fibrous tissue stretch across the interval between the ends of the tendon occasionally an ossifying hematoma is encountered The ends of the tendon become thickened bulbous and sclerotic. When the patient contracts the quadriceps muscle a wide sulcus between the patella and the muscle is readily discernible (Fig 161) Repair of the defect is achieved in the same manner as was described for fresh lesions However, in all cases the author takes the added precaution of reinforcing the suture line by a wide strip of fascia lata swung from the same side, the distal attachment of the flap is left intact (Fig 159) This added step is of particular importance when considerable difficulty is encountered in pulling the end of the shortened quadriceps muscle to the lower fragment or to the base of the patella On occasions this can be achieved only by lengthening the extensor apparatus by a preliminary plastic procedure

Postoperative Management

At the completion of the operation a compression bandage is applied on the limb splinted by a molded posterior plaster splint extending from the toes to the upper one third of the thigh, holding the foot at 90 to the leg and the knee extended fully After 10 or 14 days the splint is removed, and a skintight plaster cylinder is applied

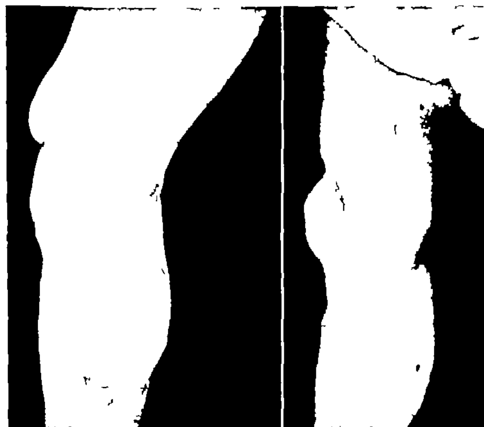


Fig 161 (*Left*) Old rupture of the quadriceps tendon (*Right*) Contraction of the quadriceps muscle. The sulcus between the muscle and the tendon becomes more pronounced.

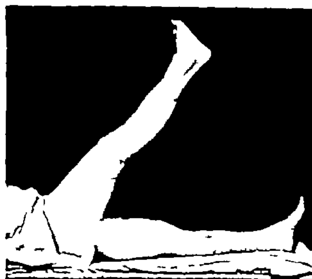


Fig 162 Same case depicted in Figure 161 Note that extension is now complete (10 weeks after the repair)

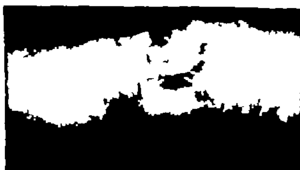


Fig 163 Case of avulsion of the patellar tendon from the tibial tubercle in an elderly woman. The soft tissues overlying the tibial tubercle were broken.

Then mild quadriceps exercises are instituted first the patient is taught simple controlled contractures of the quadriceps, and later with the aid of a balanced suspension apparatus straight leg raising is commenced. The cast is removed at the end of 5 to 6 weeks and protected weight bearing is allowed (using crutches) Now the patient is placed on a strenuous regulated regimen comprising exercises designed to restore quadriceps power and volume and to increase flexion of the knee joint Generally



Fig 164 Roentgenograms of case depicted in Figure 163 Note avulsion and comminution of the tibial tubercle with upward retraction of the patellar tendon

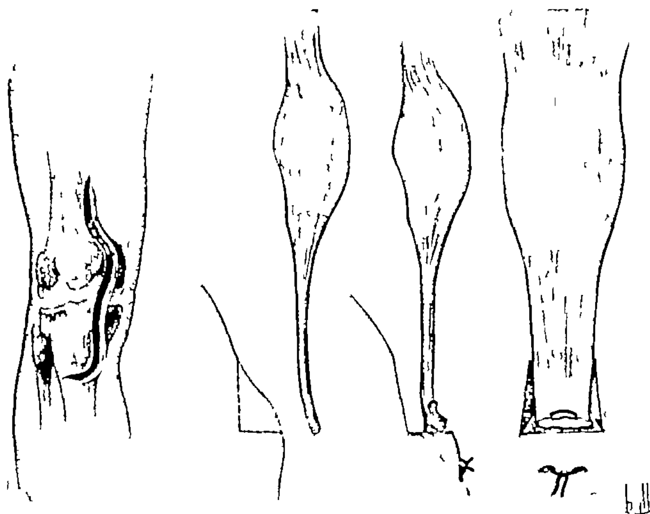


Fig 165 (A) Reattachment of the patellar tendon to the anterior surface of the tibia

8 weeks postoperatively extension should be 180 or nearly so and flexion should be between 110 and 130° (Fig 162) Power of the quadriceps muscle and flexion of the knee should increase progressively so that from 8 to 12 months after surgical repair optimum function is restored In elderly patients complete flexion seldom is achieved following repair of a ruptured quadriceps tendon However if 90° flexion is obtained, the result should be considered satisfactory because this range of motion is sufficient to meet the functional requirements of the individual.

AVULSION OF PATELLAR TENDON FROM TIBIAL TUBERCLE

The mechanism of this lesion is similar to that of rupture of the quadriceps tendon It also is encountered most frequently in individuals past middle life. The incidence of the disorder is far less than that of rupture of the quadriceps tendon The pertinent clinical features are a history of stumbling while descending steps or coming down an inclined plane, of severe pain in the knee associated with a loud snap and of falling to the ground Clinical examination reveals varying degrees of swelling of the knee particularly if the patient struck the knee against the step or the ground, a high riding patella, a sulcus which is readily palpable immediately above the tibial tubercle, tenderness on pressure over the tibial tubercle and the distal end of the patellar tendon and loss of active extension (Fig 163) Roentgenograms may exhibit fragmentation or avulsion of the proximal portion of the tibial tubercle (Fig. 164)

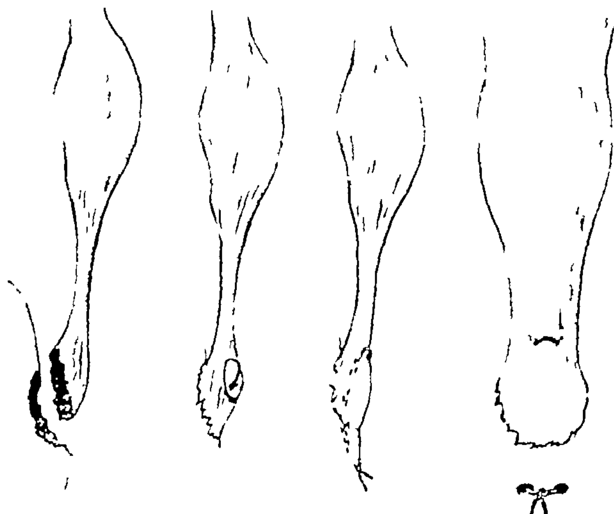


Fig 165 (B) If a large piece of bone is avulsed with the tendon it may be anchored to the tibia with a screw or piece of wire

Treatment

If possible the integrity of the extensor apparatus should be restored immediately by surgical intervention in order that shortening of the quadriceps muscle may be prevented (Fig 165) The author employs a median parapatellar incision the lower end of which swings laterally crossing the anterior tibial crest immediately below the tibial tubercle The skin and the subcutaneous tissue are reflected outward exposing the patella the patellar ligamentum and the tibial tubercle *All blood clots and frayed shredded strands of tissue and periosteum are trimmed away from the end of the tendon and the upper end of the tubercle* Now the severity of the pathology can be determined *As a rule the defect between* the tendon and the tibial tubercle extends medially and laterally for varying distances *through the medial and the lateral patellar* retinaculi With a sharp osteotome a ledge ½ inch deep and at right angles to the longitudinal axis of the tibia is cut out of the proximal portion of the tibial tubercle Two *drill holes are made in the long axis of the* tubercle beginning below on the tubercle and directed upward and inward so that the exits are on the raw surface of the ledge Downward traction is made on the patella *with a towel clip* a mattress uture of braided silk or kangaroo tendon is pa sed through the lower end of the tendon and the drill holes and is tied on the anterior ur face of the tubercle (Fig 165 A) The defect *in the medial and the lateral fibrous expan*

sions of the quadriceps muscle is closed with interrupted cotton sutures In the event that a small piece of bone is avulsed from the tubercle it is excised, and the operation is performed as described above If a large piece of bone is avulsed with the tendon still attached it should be replaced in its anatomic position and anchored with a screw or a piece of wire (Fig 165 B) This latter lesion occurs in young people but rarely in patients past middle life at least, *the author never has seen such a case* Post operative management is conducted in the same manner as that described for rupture of the quadriceps tendon

AVULSION OF PATELLAR TENDON FROM PATELLA

As recorded previously, avulsion of the patellar tendon is encountered most fre quently in the early decades of life The mechanism is the same as that described for rupture of the quadriceps tendon. Gen erally the lesion comprises complete avul sion of the tendon from the apex of the patella the tear extends into both the medial and the lateral patellar retinaculi occasionally, a small fragment of bone is avulsed from the lower pole of the patella.

The clinical picture does not differ from that of rupture of the quadriceps tendon There is a history of injury followed by severe pain in the knee and loss of active extension of the leg The patella assumes a higher position on the anterior surface of the femur than the patella of the normal extremity A transverse defect is palpable *between the lower pole of the patella and the* patellar ligament. No change of tension is noted in the tendon when the quadriceps is contracted Roentgenographic study may disclose a high riding patella and a fragment of bone lying at a distance distal to the apex of the bone Roentgenograms taken to show soft tissue structures may reveal a break in continuity of the patellar tendon in the region of the apex of the patella.

Treatment

The rupture is exposed through a U shaped skin incision (Fig 166) Loose frag ments of bone and strands of devitalized tissue are excised The defect is flushed

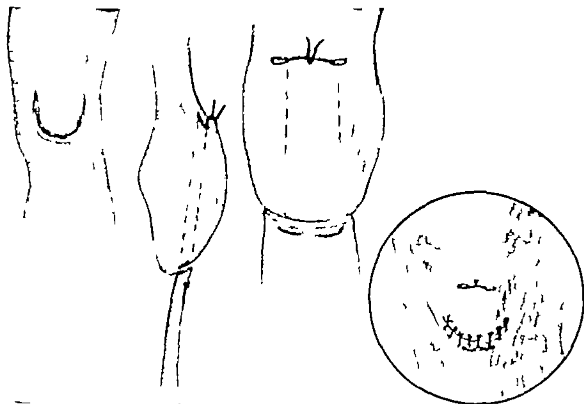


Fig 166 Reattachment of patellar tendon to the patella.

thoroughly with normal saline solution and all blood clots are removed Repair of the defect is achieved in the same manner as that described for rupture of the quadriceps tendon Tears in the medial and the lateral expansions of the quadriceps muscle are closed with interrupted cotton sutures A wide strip of fascia lata swung from the lateral aspect of the thigh may be used to reinforce the repair

OLD RUPTURES OF THE PATELLAR TENDON

Occasionally untreated cases of long duration are encountered Adequate management of these lesions is made difficult because of shortening of the quadriceps muscle a sequel which invariably occurs In some instances in order to effect a repair some preliminary lengthening procedure must be done on the quadriceps muscle Some workers advocate stretching of the muscle by skeletal traction a Kirschner wire is passed transversely through the upper portion of the patella and traction is applied (3 to 5 pounds) for 2 to 4 weeks In 2 cases in the author s series the lesion had existed untreated for 1½ and 2 years respectively On exploration of the affected areas the second case disclosed complete disintegration of the patellar ligament a large irregular mass of heterotopic bone occupied the interval between the inferior pole of the patella and the tibial tubercle (Fig 167)

In both these cases a repair was performed in the same manner The region was exposed by a hockey-stick skin incision in the median parapatellar region beginning 2 inches above the base of the patella (Fig 168 A) The incision extended distally to a point below the tibial tubercle then curved laterally to the lateral margin of the tibial crest The skin was reflected outward and the patella the infrapatellar region and the tibial tubercle were exposed All scar tissue and heterotopic bone were excised A strip of fascia lata 2½ by 5 inches was obtained from the opposite thigh from this a new patellar ligament was constructed The proximal end of the fascia lata strip was placed over the patella and anchored to its periphery by silk sutures passing through drill holes previously made in the bone (Fig 168 B) The distal end of the strip was divided longitudinally into 2 halves. Next the tibial tubercle was prepared to receive the two strips of fascia lata. A bony ledge ½ inch deep was cut out of the upper portion of the tubercle its upper surface lay in the horizontal planes Two drill holes were made in the long axis of the tubercle beginning below and directed backward and upward so that the exit was on the raw surface of the ledge (Fig 168 C) The two fascial strips were passed through the drill holes tied and sutured to each other the ends also were sutured to the periosteum of the tibia Interrupted cotton sutures were employed for this purpose While the two fascial strips were being anchored moderate downward traction was made on the patella with a towel clip

The result in both cases was surprisingly good At the end of 8 months in the first case and 1 year in the second active extension was possible to 180 and flexion to 70° and 90° respectively The postoperative management was the same as that described under rupture of the quadriceps tendon

RUPTURE OF ISOLATED GROUPS OF FIBERS OF COMPONENTS OF QUADRICEPS MUSCLE

This lesion is usually the result of violent contraction of the affected muscle or of direct trauma to the part with sufficient intensity to divide the underlying muscle fibers It is encountered frequently in muscular young individuals participating in strenuous competitive athletics (football basketball etc)

Frequently the vastus internus is traumatized by direct force One patient ob



Fig 167 Old rupture of the patellar tendon Note heterotopic bone in the tendon and high position of the patella

Fig 168 Reconstruction of patellar tendon for old rupture in which the tendon has undergone complete degeneration

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Fig 168 Reconstruction of patellar tendon for old rupture in which the tendon has undergone complete degeneration.



FIG. 169 Early myositis ossificans in the upper thigh following severe direct trauma to the part 4 weeks prior to the taking of this roentgenogram.

served by the author was struck on the anterior aspect of the thigh by a baseball bat. Essentially the local pathology comprised rupture of fibers of the muscle and hemorrhage In the case noted above a few hours after the injury the thigh became uniformly enlarged and tense, and the knee was flexed 160 An attempt to increase the degree of flexion initiated excruciating pain

Injury to the vastus internus is of particular importance because of the predilection of myositis ossificans traumatica to develop in this muscle Especially in children the possibility of this unfavorable sequela must be anticipated, and treatment instituted accordingly

Immediate treatment comprises bedrest uniform compression of the entire limb from the toes to the groin and application of ice bags to the thigh After 2 to 4 days swelling diminishes indicating cessation of active bleeding and beginning of absorption of the hematoma. Now radiant heat may be applied to hasten absorption, and mild exercises may be instituted to restore flexion and extension at the knee joint Surgical evacuation of the hematoma is never indicated, in fact, any surgical trauma may encourage the development of myositis ossificans (Fig 169) For the same reason forceful therapeutic measures such as kneading massage and passive pump-handle" motions of the leg in an attempt to increase flexion are contraindicated In the event that this complication occurs the extremity must be guided on a course of treatment in which extreme gentleness is the cardinal feature. Surgical intervention never is justified in its early stage As a rule the process progresses to a certain stage then retrogresses, the newly formed bone being absorbed spontaneously Removal of the bone is indicated only when the process exhibits no further tendency to progress and when the bone interferes with normal function of the limb Many months must elapse before this quiescent phase is reached and before the contemplated surgery can be performed with assurance that the pathologic process will not be reactivated It was noted under the discussion of bone tumors that in the early stages of development myositis ossificans may be diagnosed erroneously as osteogenic sarcoma.

The anatomic position of the vastus lateralis situated under the tough fibrous iliotibial tract affords it considerable protection from direct violence However one case a laborer came under observation with a history of direct violence to the upper part of the thigh which caused a large herniation of the vastus lateralis The initial findings were consistent with hemorrhage and trauma to the vastus lateralis the upper lateral region of the leg was swollen enormously The patient was treated conservatively along the lines outlined for ruptures of the fibers of the vastus internus. Three months later the patient appeared with a mass on the upper lateral a pect of

the thigh measuring 5 cm wide and 8 cm long It was soft and slightly tender on pressure, and a distinct defect was palpable in the fascia lata. The pertinent clinical features were a sense of instability in the extremity and pain on walking or standing Because of the severity of the symptoms, the patient was unable to return to his work A repair was effected by overlapping the edges of the defect in the fascia lata Several muscle hernias have been observed following the removal of strips of fascia lata none of these gave rise to functional disorders of the limb However some observers have recorded that disability may occur

Traumatic severance of the fibers of the vastus medialis occurs more frequently than is generally realized It is invariably a concomitant feature of primary traumatic dislocation of the patella As previously recorded the lesion per se and its significance relative to the future functional capacity of the quadriceps mechanism are frequently overlooked at the time of the injury The management of this disorder has been discussed under the treatment of primary dislocations of the patella

Severe direct trauma to the muscle while it is contracting forcefully is capable of inflicting major tears in the muscle One such case was encountered in a patient whose thigh was trapped between the side of a ship and a launch which was being lowered into the sea The muscle was crushed and divided against the shaft of the femur As has been pointed out by Smillie, immediate operative repair of freshly traumatized muscle fibers is likely to fail A better repair is achieved if sufficient time is allowed to elapse in order that firm scar tissue may form subsequently the scar tissue is excised and the defect is approximated by sutures of fascia lata. Such a plan was carried out in the aforementioned case the patient attained an excellent functional result

Minor tears of the fibers of the rectus femoris muscle are encountered frequently in youths engaged in strenuous sports Many of the tears are too small to change the general configuration of the muscle mass, they parade under the diagnosis of contusion or intramuscular hematoma Occasionally, a sufficient number of fibers is involved to allow the formation of a visible, palpable defect The mechanism is either one of violent contraction of a group of muscle fibers or direct violence to the muscle during the stage of contraction On occasion a large portion of the muscle may be severed by a heavy falling object which crushes the muscle against the femoral shaft.

In fresh injuries the severity of the symptoms and the amount of disability depend upon the size of the rupture and the intramuscular hemorrhage Generally, some swelling of the affected region is demonstrable pressure over the area elicits tenderness and contraction of the rectus femoris is painful Later larger rents in the muscle exhibit a visible palpable defect with its size and borders accentuated by contraction of the muscle

As a rule, the intensity of the symptoms in recent injuries is not severe, simple measures such as rest, compression bandage and ice bags on the part suffice to relieve the discomfort and reduce the swelling Even in major ruptures the extent of the residual disability is minimal in degree and does not require surgical intervention Moreover, repair of a defect in muscle tissue is difficult, and recurrence of the lesion is a frequent sequela In the light of the knowledge that operative measures provide little or no improvement in the functional capacity of the muscle the procedure is not warranted except in isolated cases

FRACTURES OF THE PATELLA

General Considerations

Fractures of the patella are relatively frequent lesions. In general they can be categoried into two major groups (1) fractures produced by direct force and (2) fractures

resulting from indirect force No hard and fast rules can be laid down for the treatment of either group Each individual case presents problems which must be analyzed and evaluated carefully before an adequate plan of management can be formulated for the case in point. Critical assessment of long term follow up studies and proper regard for the role that the patella plays in the over all efficiency of the extensor apparatus are factors which are responsible for the evolution of the methods of treatment commonly employed at the present time Nevertheless there still exists a wide diversity of opinion relative to the most efficacious methods, especially as to the advisability and the indications of patellectomy

Many of the controversial opinions and the resulting confusion can be traced to the publication of Brooke in 1937 who launched the premise that the patella was not a functional structure but a phylogenetic inheritance He further contended that the organ was a sesamoid bone (a belief still widely accepted by many workers) and did not develop in response to any functional demand and that the extensor mechanism functioned more efficiently without the patella Study of the embryologic development of the knee joint and comparative anatomy of the patella, analysis of the functional mechanism of the extensor apparatus and critical studies of a series of patients with patellectomies fail to provide data supporting the theories noted by Brooke The patellofemoral joint develops along lines paralleling those of the femorotibial joint this is definite proof that the organ is not a sesamoid bone Studies conducted on the comparative anatomy of this bone reveal that in the erect position the patella plays an even greater role in the mechanics of the knee joint than in animals holding the articulation in a flexed or a semiflexed position From the viewpoint of function the patella increases the strength of the quadriceps muscle by improving leverage This is accomplished by deflecting the line of pull of the motor force necessary to extend the joint anterior to the center of the articulation so that it acts at an angle instead of in a straight line to the bony elements of the articulation This arrangement provides for greater stability of the femur and the tibia at the knee joint and for maintenance of equilibrium It must be conceded that many individuals in whom the patella has been removed can extend the knee with good power, and the joint is sufficiently stable to meet the ordinary functional demands of locomotion and the upright position However these observations do not justify the premise that the patella does not add to the mechanical efficiency of the knee joint and that an otherwise normal joint would function as efficiently or even better without a patella The clinical observations noted by the author in a series of patellectomies performed for varied reasons support those of Haxton Haxton showed conclusively that in patients with and without patellae the power of extension of the knee increased progressively as the arc of extension approached 180° for example greater force is exhibited at 160° than at 140 and more force is produced at 140 than at 120° The knees of patients with patellectomies, when compared with the normal side, disclosed an increase in power considerably less than that on the unaffected side during extension of the joint This observation points to the significant role that the patella plays in the efficiency of the extensor mechanism It is common clinical knowledge that the loss of volume of the quadriceps is greater in cases of patellectomy than in those in which all or part of the bone is left in situ Also the period for return to normalcy is greater in the former group and in many instances in spite of intensive exercises the quadriceps exhibits permanent diminution in volume as compared with the normal muscle This feature per se is sufficient reason for impairment of extension power and stability of the knee joint Another important function of the patella com

monly overlooked, is its protective action to the anterior aspect of the joint In man the knee joint occupies a very vulnerable position, loss of the protection afforded by the patella predisposes the knee to repeated minor traumata with the cumulative effect producing varying degrees of osteo-arthritis

Formation of heterotopic bone following excision of the patella is not an infrequent occurrence. According to Wass and Davies, this complication is responsible in a large measure for the pain and the impaired motion at the knee joint They noted that small areas of calcification and ossification may cause no interference in function however larger areas may reduce the elasticity of the quadriceps tendon, thereby decreasing the range of flexion of the joint (Fig 170) Patellectomy changes considerably the external configuration of the joint When the knee is flexed the abnormality is very striking Some patients, particularly women, look at the disfiguration with disfavor

In spite of the many points discrediting the advisability of patellectomy, there are specific indications which justify the procedure. However, the instances justifying the procedure are few, and indiscriminate removal of the patella *should be condemned*



Fig 170 Note evidence of calcification and ossification in quadriceps tendon following patellectomy This reduces the elasticity of the tendon, hence decreasing the range of flexion of the joint.

Mechanisms

It was recorded previously that fractures of the patella are sustained either by direct or indirect violence They are frequent in adults but are observed only rarely in children and adolescents. The mechanism of indirect force is encountered most commonly in middle aged individuals In elderly people this mechanism usually results in rupture of the quadriceps tendon. Generally indirect force produces a transverse fracture The mechanism is one of stumbling down steps or an incline, the quadriceps muscle contracts violently as the entire weight of the body is thrown on the extremity with the knee semiflexed In this position the patella rides high on the femoral condyles and is fixed and subjected to the tension of the patellar tendon below and the quadriceps muscle above Sudden forceful contraction of the quadriceps snaps the patella transversely over the condyles of the femur Occasionally, transverse fractures are sustained in running and falls or jumping from a height here the same mechanism is active The patellae are fractured before the knees strike the ground However, one can conceive readily how a transverse fracture with wide separation of the fragments may be sustained with both an indirect and a direct force acting This occurs when a direct blow is delivered to the anterior surface of the kneecap with the extremity in motion and semiflexed Case B C illustrates this point. The patient, a young lady, was engaged in a hockey game, while skating across the rink she was struck on the patella by a hockey stick She felt a loud snap in the knee and fell instantaneously to the ice. Examination revealed a transverse laceration of the skin measuring 4 cm Immediately over the patella the bone was severed transversely into two almost equal segments

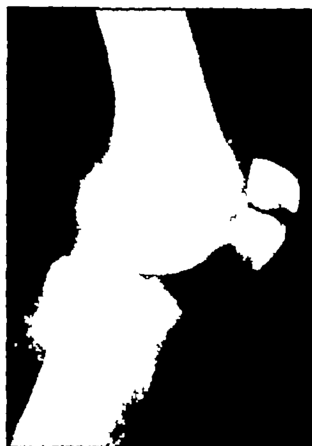


Fig 171 Transverse fracture resulting from indirect force There is some comminution of the lower segment. In this case separation of the main fragments is minimal.

Direct forces applied to the anterior surfaces of the patella usually result in comminuted fractures the acting forces are usually kicks or blows on the outer surface of the bone Several cases have been observed in which the patient s knees were pushed forcibly against the dashboard when the automobile in which he was riding came to a sudden unexpected stop

Table 6 Types and Incidence of Patellar Fractures

Transverse fractures		34
Fragments of equal size	9	
Small upper fragments	6	
Small lower fragments	19	
Comminuted fractures		17
Polar fractures		7
Vertical fractures		4
Total cases		62

Associated Pathology

Adequate comprehension of the pathology associated with the two groups of fractures is essential in order to choose the method of treatment which will produce optimum function of the knee joint Also understanding of the severity of the pathology provides the surgeon with valuable data on which the results of treatment and the future status of the joint may be determined

The pertinent difference between the pathology encountered in the two groups of fractures is the varying severity of disruption of the quadriceps extensor mechanism sustained at the time of injury As described previously indirect forces usually produce a transverse fracture of the patella In most cases the fracture line traverses the distal half of the bone Frequently, the lower segment may be broken up into two or more fragments (Fig 171) Invariably, this type of fracture exhibits separation of the principal fragments and more important tears of the medial and the lateral patellar retinaculi and of the anterior portion of the fibrous and the synovial capsules of the joint The extent of the tears depends upon the severity of the force expended to produce the fracture occasionally they extend laterally and medially to the anterior margins of the collateral ligaments Also the fascioperiosteal covering of the patella is shredded and torn and fragments of it may be found interposed between the main bony elements. It becomes apparent that in the event of such trauma bleeding in variable amounts ensues Hence the joint cavity is filled with blood clots and serosanginous fluid Much of this fluid and blood escapes into the surrounding soft tissues Also it is obvious that this fracture communicates with the joint cavity in all instances Occasionally fractures produced by indirect trauma reveal little or no separation In such instances the lateral expansions of the quadriceps muscle may be stretched or even frayed slightly but its integrity is not interrupted

In all fractures of the patella the quadri

Fig 172 Fracture of the patella with wide separation of the fragments due to upward displacement of the proximal fragment. Here there is extensive tearing of the medial and the lateral patellar retinaculi



Fig 173 Fracture of the patella due to direct violence Note comminution and minimal separation of fragments.



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Fig 173 Fracture of the patella due to direct violence. Note comminution and minimal separation of fragments



Fig 174 Aseptic necrosis of the proximal fragment Most probable cause is impairment of the blood supply at the time of injury Note the incongruity of the articular surfaces of the wired fragments.

ceps muscle tends to pull the proximal fragment upward while the distal fragment remains stationary occasionally the latter may exhibit a forward tilt The distance that the proximal fragment travels upward is governed by two factors (1) the severity of the tears in the patellar retinaculi and the joint capsule and (2) the intensity with which the force acts after the continuity of the patella is severed In severe lesions the proximal fragment may be displaced upward from 6 to 8 cm. above its normal anatomic position the displacement is even greater in old untreated cases All fragments tend to maintain a mid line position there is rarely any appreciable lateral displacement discernible (Fig 172)

Fractures resulting from direct force usually exhibit only minimal displacement of the fragments the patellar retinaculi and the joint capsule remain intact (Fig 173) Exceptions to this are found when a combination of forces produces the lesion then some separation occurs As a rule the patella is broken up into 3 or more fragments the fracture lines may extend in any direction On rare occasions a portion of the periphery of the patella may be fractured often this lesion is described as a marginal fracture Even more rare are single fractures through the long axis of the patella or through the coronal plane

Whereas in the first group of fractures the external coverings of the knee rarely are implicated, in the latter group varying severity of damage usually is noted in the skin and the subcutaneous tissue Occasionally the skin wound communicates with the fracture and hence must also communicate with the joint cavity

Frequently loose particles of bone are encountered lying free in the joint cavity and the suprapatellar pouch or attached loosely to the larger fragments of the patella Osteochondral fractures implicating the articular surface of the patella or the patellar surface of the femur may occur Very rarely, there is complete disruption of the blood supply of one of the main fragments this may not be manifested until several months have elapsed Roentgenographic studies reveal uniform increased density of the involved fragment indicating the true nature of the lesion (Fig 174) Finally trauma of varying intensity may be inflicted upon the opposing articular surfaces of the patella and the femur predisposing the patellofemoral articulation to osteoarthritis

Clinical Features

One should have no difficulty in establishing a diagnosis of fractures of the patella Overlooking the lesion is an indication of either gross negligence or inexperience The diagnosis is arrived at readily by the history the subsequent disability the physical examination and finally the roentgenographic studies The usual history in cases of indirect violent trauma is one of stumbling or

falling followed by sudden pain and a snap in the knee joint. The patient falls to the ground and immediately becomes aware that his leg cannot be extended actively and will not support the body weight without buckling In cases of direct trauma there is a history of a blow to the anterior surface of the patella.

In fractures with separation of the fragments physical examination reveals varying degrees of swelling, usually immediately over the anterior surface of the bone giving it a domelike appearance The tissues of the knee do not appear to be under great tension, such as one observes in traumatic synovitis or hemarthrosis Great tension of the joint is never attained because the synovial fluid and the blood escape through the defect in the quadriceps apparatus and are dispersed throughout the surrounding soft tissues. The swelling immediately over the patellar region results from localized accumulation of blood in the tissues in the immediate vicinity of the fracture A sulcus can be demonstrated readily by palpation of the anterior patellar region Occasionally the upper and the lower poles of the patella may be grasped between the index fingers and the thumbs and displaced laterally in opposite directions, indicating a break in the continuity of the bone The most significant clinical manifestation is loss of active extension of the leg on the thigh all attempts to execute this movement are accompanied by excruciating pain

Fractures with little or no separation of the bony fragments exhibit a different clinical picture. Swelling of the knee is not too concentrated on the anterior surface of the kneecap but is more or less uniform in nature (except for a small local swelling immediately over the patella) resembling that of traumatic synovitis and hemarthrosis Although the maneuver is associated with pain, the patient is able to extend the knee actively No abnormality in the configuration of the patella is demonstrable by palpation however pressure over the anterior surface of the bone elicits severe pain. In this group of cases the diagnosis can be determined only by roentgenographic investigation Roentgenograms should be taken in the anteroposterior, the lateral and the vertical views The vertical or axial view may provide information which is not attainable by routine anteroposterior and lateral views it is of especial value in depicting longitudinal fractures and congenital malformations of the patella.

Considerations Governing Treatment

Critical assessment of reported series of long term follow up studies of fractures of the patella reveals that many methods of treatment employed at the present time need revision, and others should be discarded except in occasional cases A recent survey by the author of 62 fractures of the patella from 1 to 6 years after treatment brought to light some interesting observations which support the findings of Scott. This worker reported a comprehensive review of 196 cases from different sources From the aforementioned investigations it becomes apparent that the patella is a very essential component in the extensor mechanism and must not be sacrificed indiscriminately After removal of the patella very few extremities return to normalcy, they exhibit permanent loss of volume in the quadriceps muscle and diminished extensor power and the anterior surfaces of the condyles are subjected to repeated traumata which under normal conditions would have been absorbed by the patella. In Scott's series only 5 per cent of the patients believed that they had a normal knee The most common complaints are a deep-seated ache in the knee joint a constant feeling of fatigue throughout the entire extremity and a sense of instability often associated with actual buckling of the joint. As previously noted these findings do not substantiate the opinions of some sources. In the light of this information primary total excision of the patella should be reserved for cases with



Fig 175 Wired fractured patella. Note incongruity of the articular surface the wire is broken and causes pain on motion.

such severe comminution of the bone that no single fragment remains of sufficient size which can be utilized to preserve the normal mechanics of the joint

When the patella is broken up into two large fragments of approximately the same size the surgeon experiences a natural urge to restore the bony elements to their anatomic position this also applies to fragments of unequal size and in rare instances to comminuted fractures Numerous operations have been designed to achieve this goal and many and varied materials are utilized as sutures some workers employ vitallium screws plates or bone pegs to maintain the reduction of the fragments Although restoration of bone fragments to their normal position is a sound principle in the treatment of fractures of all bones the patella is the exception to the rule Follow up studies reveal that regardless of how meticulously the fragments are approximated some displacement recurs resulting in incongruity of the articular cartilage of the patella (Fig 174) This feature leads to chondromalacia and varying intensities of osteoarthritis in the patellofemoral joint The factors responsible for displacement of the fragments are (1) continuous distraction by the quadriceps muscle at the fracture site and (2) loss of fixation caused by absorption of some bone at the line of fracture It is common knowledge that the patella exhibits relatively poor power of osteogenesis for this reason and the ones enumerated above fibrous union and nonunion are more common than is generally realized In the author's series there were 3 cases treated by a circumferential wire loop and 10 by a wire loop passing through both fragments in the manner described by Magnuson.

Table 7 Complications Following Treatment of Patellar Fractures by Approximation of the Fragments

Refracture	1
Quadriceps tear	1
Wires broken	4
Fibrous union	3
Nonunion	2
Total cases	13

It was interesting to note that in the majority of these cases some malpositioning of the articular surfaces of the patellar fragments was demonstrable by postoperative roentgenographic studies this was true even in those cases in which the fragments appeared to be in their true anatomic position at the time of operation indicating that it is extremely difficult to achieve perfect restoration of the fragment Of the 13 cases the wire loop broke in 4 cases with further subsequent displacement of the fragments (Fig 175) fibrous union occurred in 3 and nonunion in 2 Failure to attain bony union results in marked inefficiency of the extensor mechanism which is reflected in

the loss of volume of the quadriceps muscle and the instability of the affected knee joint In addition, malunion and inadequate bony union predispose the patient to recurrent traumatic synovitis and osteoarthritis of the patellofemoral joint Also, one case of malunion in this series had a second fracture of the patella and one case, rupture of the quadriceps tendon. Undoubtedly, the last two complications were the result of quadriceps inefficiency which allowed the knee to give way, inflicting undue stress on a weakened patellar or quadriceps tendon In view of the high incidence of unsatisfactory results recorded above, it becomes apparent that operations designed to restore and maintain the integrity of the patella fall short of the goal desired by both the surgeon and the patient. Internal fixation of fractures of the patella is justified in the exceptional cases. The ideal fracture for this method is one in which the fragments are equal in size or almost so, and can be approximated with perfect anatomic alignment. Any comminution of the fragments should preclude the use of this method

Much can be said in favor of the method of treatment that retains one large fragment of the patella this may occupy either a superior or an inferior position The normal configuration of the knee joint is preserved this feature is particularly desirable in women. There is no alteration in the functional mechanics of the extensor apparatus the remaining fragment is still capable of displacing the line of pull of the quadriceps muscle anterior to the center of the knee joint. The capsular structures on the anterior portion of the joint and the anterior portions of the articular surfaces of the femoral condyles still are afforded protection by the remaining fragment Furthermore, Thomson pointed out that the procedure is concerned primarily with union between tendinous structures and bone thereby eliminating the possibility of non union or of fibrous union between fragments which naturally possess poor powers of



Fig 176 Healed fracture of the patella of the same case depicted in Figure 173 treated by nonoperative measures.

osteogenesis Also, he noted that the method permits early restoration of function to the extremity, hence reducing to a minimum the period of disability and the possibility of refracture Comparative end result studies of the different procedures employed emphasize that permanent dysfunction of the knee is considerably less when one fragment of the patella is retained than when the bone is excised in toto or all fragments are preserved and reassembled in an attempt to restore normal anatomy

Preferred Methods of Treatment

In the light of the aforementioned observations it becomes apparent that each case of fracture of the patella presents specific problems which must be analyzed carefully before treatment is instituted Failure to do so jeopardizes the end result and may lead to great disability and perhaps to a second operation. Regardless of the method of management chosen, the patient's period of disability is shortened, and less dysfunction of the knee results if definitive treatment is undertaken immediately Scott recorded that the average time of postoperative disability in 195 cases varied from 3 6 to 5.3 months and that the time was appreciably less when operation was performed before the fourteenth day than when



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it was performed later The author has established a policy that all fractures of the patella necessitating operative procedure are operated upon in the first 24 hours after the injury provided that no contraindications to surgery exist In general the treatment of all fractures of the patella falls into one of two groups (1) nonoperative treatment or (2) operative treatment

Nonoperative Treatment

Conservative measures are employed in fractures showing no separation of the fragments and in which the continuity of the quadriceps apparatus is intact These fractures comprise incomplete or fissure fractures of the patella resulting from indirect force and fractures sustained by direct force which exhibit multiple fissures or even comminution of the fragments but no displacement or incongruity of the articular cartilage (Fig 176)

It was noted previously that in these fractures blood accumulates in the joint cavity producing diffuse swelling of the knee not unlike that observed in traumatic synovitis The first step in the treatment is aspiration of the blood with a wide bore needle This is done under aseptic conditions with the knee extended Local anesthesia is adequate for this purpose A posterior molded plaster splint is applied extending from above the malleoli to the upper region of the thigh, and bags full of ice are placed over and on either side of the knee Within 2 or 3 days the knee begins to approach normalcy on rare occasions aspiration of blood from the joint cavity must be repeated Next a skintight plaster cylinder is applied, with the knee fully extended from 2 inches above the malleoli to the upper portion of the thigh (Fig 177) The next day weight bearing on crutches is permitted Also quadriceps exercises to preserve muscle tone and volume are instituted at this time they comprise rhythmical contractions of the quadriceps muscle in the cast and active straight leg raising Depending upon the severity of the fracture the cast is removed after 4 to 8 weeks This is followed by a regimen of intensive exercises designed to obtain maximum quadriceps power and to restore normal joint function

Operative Treatment

In general fractures of the patella requiring surgical intervention are treated by one of three methods (1) the bony fragments are replaced in their normal anatomic position and made secure by some form of internal fixation (2) one large fragment is



Fig 177 Plaster cylinder extending from above the malleoli to the upper one third of the thigh The knee is in the extended position.



Fig 178 Fracture of the patella treated by excision of the upper fragment and reattachment of the quadriceps tendon to the lower fragment.

retained to which is sutured the opposing tendon, and all other fragments are excised and (3) all patellar fragments are removed

It is essential to emphasize that the incision utilized for the operation should give adequate exposure of the entire patellar and parapatellar regions in order to evaluate properly the severity of the injury both to the patella and to the lateral expansions of the quadriceps muscle In cases with separation of the bony fragments the interior of the joint should be inspected meticulously all blood clots and loose fragments of bone must be removed Finally, tears in the medial and the lateral retinaculi of the patella and in the capsule and the synovialis must be repaired carefully with interrupted sutures Occasionally, the lateral expansions of the quadriceps are shredded and frayed severely, making the repair extremely difficult in such instances the suture line may be reinforced with a strip of



Fig 179 Fracture of the patella. Treated by excision of the smaller lower fragment and reattachment of the patellar tendon to the upper fragment.

fascia lata The author has found this necessary in several cases in elderly patients

RETENTION OF ONE LARGE PATELLAR FRAGMENT

In the hands of the author this method has given the best long term results this has been the experience of other workers In transverse fractures with fragments of equal size showing any appreciable separation the lower fragment is excised and the opposing tendon is sutured to the upper fragment If the fragments are of unequal size the smaller of the two is enucleated In comminuted fractures with displacement if one fragment is sufficiently large the large fragment is retained and all others are excised (Figs 178 to 180) In all polar fractures if the displacement or comminution is present the separated fragment or fragments are removed (Fig 180) Finally in ununited transverse fractures or cases of fibrous union producing symptoms in the patellofemoral joint the smaller fragment may be excised and the remaining fragment is remodeled to receive the opposing tendon

Technic (Figs. 181, 182) Usually the operation designed by Thomson is employed Exposure of the patella may be achieved either through a median parapatellar incision or an inverted U incision the author prefers the latter The use of a tourniquet facilitates the operation

A U skin incision is made with its base over the distal portion of the patellar tendon The upper flap comprising skin and subcutaneous tissue is reflected upward exposing the patella and the parapatellar region (Fig 181 A) At this time the severity of the lesion can be established fully Particular attention should be paid to the limits of the tear in the lateral expansions of the quadriceps muscle occasionally they extend to the anterior margins of the lateral collateral ligaments (Fig 181 B) Blood clots and loose bony fragments and spicules are flushed out and curetted from between

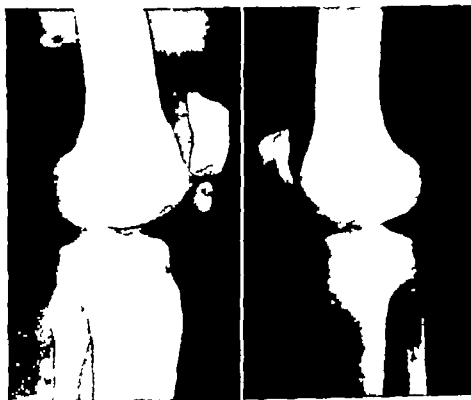


Fig 180 Fracture of lower pole of the patella The lower fragment was excised

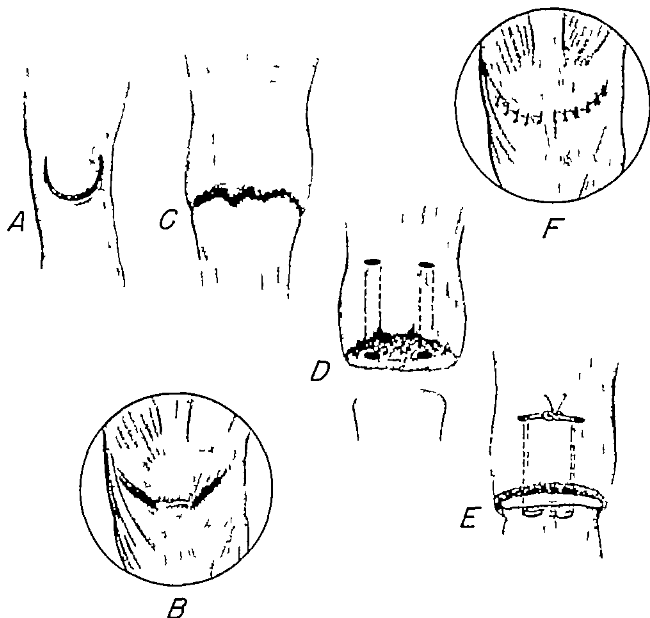


FIG 181 The larger upper fragment is retained and is approximated to the opposing tendon by a mattress suture. The tears in the medial and the lateral retinaculi are repaired by interrupted sutures (Thomson)

the larger attached fragments, and all blood clots are flushed out of the joint cavity and the suprapatellar pouch Care should be taken not to traumatize the synovial lining the use of rough dry gauze should be avoided If the superior fragment (which is usually the largest) is to be retained all other fragments are excised (Fig 181 C) Then the fractured surface is made ready to receive the opposing tendon by trimming its margins and creating a flat surface which is at right angles to the long axis of the patella. This is achieved best by using a sharp bone biter with flat broad blades Two parallel holes are drilled in the bone They are directed downward and slightly posteriorly, opening on the fractured surface just anterior to the articular cartilage (Fig 181 D)

Now the tendon is prepared for suturing to the bone all loose devitalized strands of tissue are cut away Numerous suture materials may be used to anchor the tendons the author prefers braided silk or

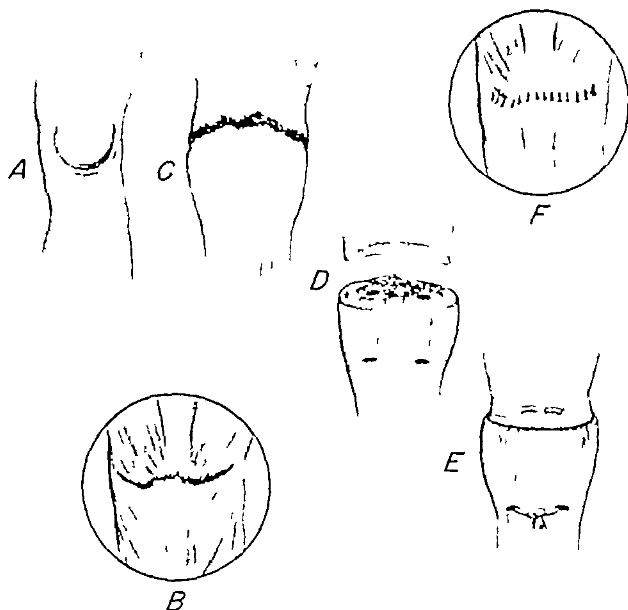


Fig 182 The larger lower fragment is retained and approximated to the opposing tendon by a mattress suture (Thomson)

tainless steel wire First a mattress suture is passed through the tendon taking several good bites of tissue then each end of the suture is passed upward through its respective drill hole in the bony fragment and drawn taut so that the end of the tendon makes firm contact with the raw surface of the bone (Fig 181 E) Next the ends are tied on the anterior surface of the fragment then the tears in the lateral expansions are repaired Beginning laterally and proceeding toward the patella the edges of the rents are approximated with interrupted sutures of No. 30 cotton (Fig 181 F)

The same technic is employed when the proximal fragment is removed or when the poles of the patella are excised (Fig 182) In comminuted fractures the fragments which are suitable to receive the opposing tendons usually are smaller than those retained in transverse fractures

Postoperative Management. At the completion of the operation a plaster cylinder is applied from 2 inches above the

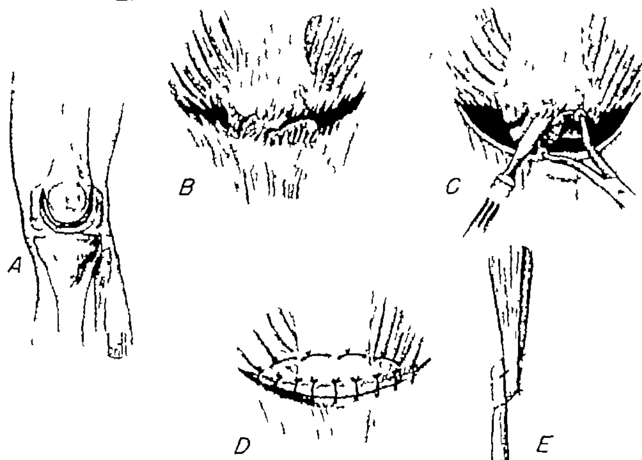


FIG 183 Method of excision of all patella fragments. The ends of the tendon and the edges of the lateral expansion are overlapped by mattress and interrupted sutures

malleoli to the upper region of the thigh After 10 days rhythmical contractions of the quadriceps muscle are instituted on a regulated regimen. Assisted straight leg raising is started at the end of 3 weeks, and weight bearing is permitted on crutches The cast is removed at the end of 4 weeks, and graduated exercises are performed to restore quadriceps power and knee motion.

EXCISION OF ALL PATELLAR FRAGMENTS

Patellectomy is a justifiable procedure in extensively comminuted fractures of the patella which do not possess a fragment sufficiently large to provide a bony anchorage for the opposing tendon. As previously pointed out it is the operation of choice in persistent and recurrent dislocation of the patella in which advanced osteo-arthritic changes have occurred in the patello-femoral joint and in malunited or ununited fractures of the patella associated with gross incongruity of the articular surface of the patella and profound secondary degenerative changes in the patellofemoral articulation It should not be done in chondromalacia of the patella if the adjacent articular surface of the femur is not seriously implicated by osteo-arthritic changes In such cases a plastic procedure on the articular surface of the patella will give a better long term end result than patellectomy, the same is true in cases of osteochondral fractures of the patella

Duncan McKeever employs a patellar prosthesis of his own design for severely comminuted fractures of the patella or for lesions which would justify excision of the patella. The author has been impressed by the results obtained by this method and

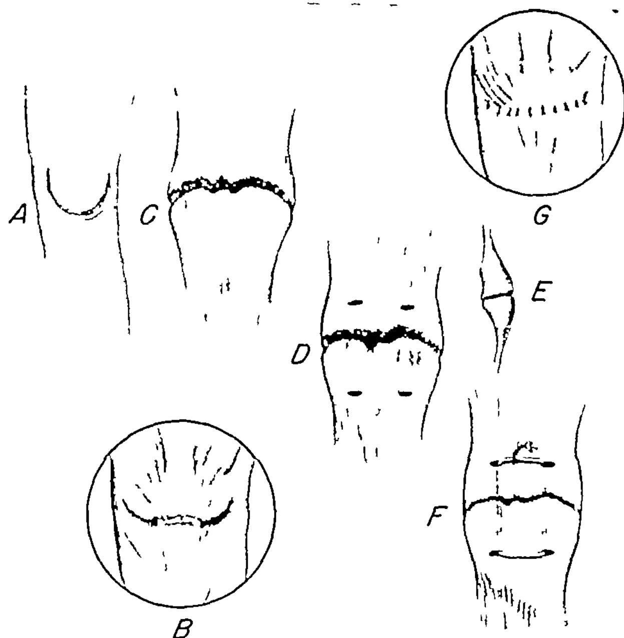


Fig 184 Wiring of the patella (Magnuson technic)

predicts that the use of a patellar prosthesis will achieve great popularity

Technic (Fig 183) The patellar and the parapatellar region are exposed by a U skin incision (Fig 183 A) By reflection upward of the skin and the subcutaneous tissue the entire anterior region of the knee joint is visualized The severity of the injury is scrutinized carefully noting particularly the damage sustained by the lateral expansions of the quadriceps muscle (Fig 183 B) All fragments are excised by sharp dissection from the quadriceps and the patellar tendons and loose shredded fragments of the tendons are trimmed away Blood clots and loose particles of bone are flushed out of the joint cavity and the suprapatellar pouch (Fig 183 C)

Simple approximation of the ends of the tendons and the margins of the rents in the lateral expansion results in lengthening of the extensor mechanism This causes loss of the last 10 or 15° of extension hence greatly reducing the efficiency of the quad

muscle as a stabilizer of the knee In order to prevent this complication ndons and the edges of the torn lat xpansions are overlapped and plicated mattress sutures to take up the slack ced by the loss of the patella The structed tendon should be shortened ot unduly tense (Fig 183 D, E) Some rs use stainless steel wire or strips of lata for suture material The author s mattress sutures of double strands 30 cotton.

old fractures of the patella or other necessitating excision of this bone the a should be enucleated from its tendi bed by sharp dissection through a verse incision The ends of the ten are treated in the manner described .

stoperative Management. After com n of the operation a plaster cylinder plied from above the malleoli to the region of the thigh Rhythmical quad s contractions gradually increasing in sity are started on the second or the postoperative day At the end of 2 s assisted straight leg raising is com ed and at the end of 3 to 4 weeks the is removed and protected weight ng is permitted Progressive exercises ned to restore maximum quadriceps r and flexion motion at the knee joint nstituted.

WIRING OF PATELLAR FRAGMENTS

e author restricts the use of this od to transverse fractures of the pa with no displacement or only minimal ation in which accurate apposition of articular surface is achieved readily nuson s technic is employed a wire is passed through both fragments

echnic (Fig 184 A to G) Exposure of patella is attained by a U skin incision its apex over the inferior fragment. skin flaps are reflected upward and ward until the base and the apex of atella are exposed After the fracture is identified the fragments are brought in accurate and firm contact by towel clips placed at either end of the fracture line.

By flexing the knee about 10° or 15° the large margins and the poles of the patella are made more accessible With a long drill two parallel holes are made in the long axis of the patella They enter the superior fragment slightly to the inner side of the medial and the lateral margins of the quadriceps tendon, and their sites of exit in the inferior fragment are close to the lateral and the medial borders of the patellar tendon The course of the drill holes should be as close as possible to the center of the antero-posterior dimension of the patella Then a piece of stout stainless steel wire is passed down the medial drill hole and up the lateral hole Next, the ends of the wire are drawn taut and twisted together, they are cut short and buried in the substance of the quadriceps tendon

Postoperative Management. A plaster cylinder is applied, and rhythmical contractions of the quadriceps are instituted the following day At the end of 2 weeks straight leg raising and protected weight bearing are allowed The cast is removed at the end of 4 to 6 weeks, and progressive exercises are instituted to develop maximum quadriceps power and joint motion.

Fractures of Patella with Superficial Lacerations

On occasion, fractures caused by direct violence exhibit abrasions and lacerations of the skin overlying the patella. In such an event preoperative measures must be carried out in order to minimize the danger of postoperative infection. If the case is seen early (within 6 to 8 hours after the injury) operative intervention is justifiable, provided that first the wounds are cleansed thoroughly with sterile green soap and water This is followed by copious irrigation of the wounds with solutions of normal saline Gentleness must be executed in this phase of the preparation of the skin Too

often the tissues are traumatized further by the use of a stiff brush or a rough gauze The author prefers to cleanse the wound with balls of cotton

Under aseptic technic the skin edges of the lacerations are excised and the wounds are closed loosely with interrupted cotton sutures Surgeon assistants and nurses now change into sterile gowns and gloves the region is redraped and the fracture is treated in the manner described for fresh closed fractures *At the termination of the* operation an aqueous solution of penicillin is injected into the operative wounds (the solution contains 250 units of penicillin per cc. 10 cc of this solution is injected routinely) Antibiotics also are administered postoperatively until it is established definitely that no infection is present As a rule antibiotics are given for 5 to 7 days

If the tissue damage is extensive and gross contamination is evident or if more than 8 hours have elapsed since the injury the wounds are cleansed gently and irrigated as described above All devitalized *tissue is trimmed away and the skin edges* are approximated loosely with interrupted sutures, but no definite surgery is attempted The limb is placed at complete rest in a posterior splint, and continuous hot wet soaks of a mild boric acid solution are applied In addition antibiotics are administered locally and systematically Usually within 8 to 10 days the wounds are clean and healed sufficiently to allow surgical repair of the fracture It may be necessary to change the course of the skin incision in order to avoid cutting through damaged skin

Open Fractures of the Patella

Severe direct violence to the kneecap may produce extensive ragged lacerations of the skin which communicate with the fracture *and hence the joint cavity It becomes obvious* that the first concern of the surgeon in these cases is to prevent contamination of the joint by pyogenic organisms This is achieved best by converting an open fracture to a closed fracture before infection occurs In cases seen within 6 to 8 hours the limb from mid thigh to mid-calf is cleansed thoroughly under aseptic technic with sterile green soap and water Care must be taken to prevent dirty fluid from entering the wound This is achieved by placing several sponges of sterile gauze in the wound Cleansing of the skin is done up to the edges of the wound After the surgeon *believes that the skin is cleansed thoroughly*, the soap is removed by pouring sterile water over the skin.

Now the wound itself is ready for cleansing. After the sterile gauze has been removed the wound is scrubbed thoroughly with sterile green soap Balls of cotton are used for this purpose While this is being done the wound is irrigated constantly with a stream of sterile saline This is continued until the surgeon is satisfied that the wound is clean Finally, the wound is irrigated by sterile saline to wash out the soapy fluid from 1,000 cc to 1,500 cc of the solution is *used for this purpose*

Next the limb is now draped for debridement of the wound The surgeon and the assistants put on sterile gowns and gloves Under a continuous stream of sterile saline *a block excision of the edges of the wound* is done The incision traverses the full thickness of the skin the subcutaneous tissue and the superficial fascia and reaches the aponeurosis of the quadriceps muscle and the fascial covering of the patella All devitalized tissues and loose fragments of bone are excised with a curet the fractured surfaces of the patellar fragments are scraped free of blood clots and other debri This phase of the operation is done slowly and meticulously It terminates only when the surgeon is convinced that the wound is free of all undesirable materials and its *sterility cannot be improved by further* surgery and irrigation At this point a decision must be made concerning subsequent treatment of the lesion

Primary definitive surgery, such as that described under the treatment of closed fractures of the patella, is permissible in wounds seen within 6 to 8 hours after the injury, provided that there is no evidence of gross contamination Lesions encountered 8 hours after the accident and showing definite marks of contamination must be treated more conservatively The synovial capsule is closed, but no repair is done in the extensor mechanism the skin is approximated loosely and the limb is put to complete rest. Penicillin solution is injected into the joint and the wound and also is administered systemically Repair is attempted only when the wound is healed and no local or systemic evidence of infection is present. This may require an interval of 2 to 3 weeks.

Old frankly infected cases are treated similarly in every feature to cases with gross contamination It is essential to close the synovial capsule in all instances after débridement of the wound is completed The skin and the subcutaneous tissues are not approximated The extremity is put to complete rest on a posterior splint, and continuous hot wet soaks are applied Antibiotics are applied locally and administered systemically in large doses After the infection has been eliminated and healing by scar tissue is complete a secondary operation is done in the extensor apparatus along the lines described for closed fractures of the patella.

Marginal Fractures of the Patella

These lesions are the result of direct violence to the margins of the patella, shearing away a fragment of its periphery There is only minimal displacement of the fragment and the quadriceps mechanism remains intact The fractures are of special importance because they are prone to give rise to pain and disability resulting from secondary degenerative changes in the patellofemoral joint. Two factors are responsible for the degenerative alterations (1) the initial force may traumatize the articular cartilage and the subchondral bone of the patellar fragment and that of the opposing anterior surface of the femoral condyle sufficiently to institute development of secondary degenerative changes, and (2) the blood supply to the peripheral fragment is inadequate to allow satisfactory healing and abort degenerative changes In many instances nonunion or fibrous union occurs regardless of the type of conservative measures employed Immobilization of the limb in plaster does not ensure bony union

With or without nonoperative treatment the immediate results are good after the acute symptoms subside normal function of the knee joint is attained After some months or even years symptoms referable to the patellofemoral joint arise, increase progressively in severity and are associated with dysfunction of the joint. Pain is increased by activity there is a feeling of stiffness in the joint and the patient is conscious of scraping of one bone against another as the knee is flexed and extended actively Rough crepitus is readily demonstrable by making firm pressure downward on the patella and moving it about on the anterior surface of the femur This maneuver is accompanied by pain Recurrent swelling of the knee resulting from an associated synovitis, is not uncommon The author has encountered one case of old marginal fracture with symptoms and disability of the joint lasting 8 years The outstanding clinical feature was persistent swelling. At operation a diffuse villonodular synovitis was noted In addition to removal of the fragment of the patella a total synovectomy was performed

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two bony elements depict the pattern of normal healthy bone the abnormality is usually bilateral (Fig 144) This is in contrast with the findings noted in old marginal fractures Here the opposing margins are irregular or even serrated the fragment exhibits areas of irregular densities approaching the appearance of cystic degeneration of bone and its articular surface is thin and uneven

TREATMENT

In view of the observations noted above it becomes apparent that the treatment of choice in marginal fractures is excision of the fragment. This is achieved readily by a small vertical incision made directly over the fragment. The fragment is enucleated by sharp dissection from the fascioperiosteal tissues of the patella and from the capsule The edges of the main fragment are made smooth and the remaining defect is closed by interrupted cotton sutures

Osteochondral Fracture of the Patella

Fractures of the osteochondral surface of the patella occur more frequently than is generally realized A survey of the literature reveals that this lesion may be one source of "loose bodies" in the knee joints First reference was made to this lesion by Kroner (1905) He reported a case of lateral dislocation of the patella in which the patella was split into two frontal sections. Of particular interest was the position of the two fragments the deeper fragment with the articular cartilage remained displaced reduction being prevented by the lateral condyle of the femur the outer fragment reduced itself Since this first report other isolated cases were recorded in the literature Some of the earlier contributors were Villar (1921) Kleinberg (1923) Stewart (1925) Krida (1928) Meekison (1937) and more recently cases have been reported by Chaklin (1939) Milgram (1943) Harmon (1945) and Coleman (1948) Usually the lesion is encountered in children and adolescents but may occur in young adults In most of t[h]
abnormal knock knee deformity

MECHANISM OF FRACT[URE]

Study of the surgical patholo[gy]
lesions leads one to conclude t[h]
force in a tangential direction i[s]
to cause the fracture Essentially
anism is one of indirect violen[ce]
tella slips over the lateral con[dyle]
femoral condyle for varying dis[tances]
force usually is sufficient to tra[u]
score the articular surfaces of
and the patella. In some instan[ces]
plete dislocation occurs and
border of the patella engages
prominent edge of the lateral
the femur Instantaneously, the
muscle contracts forcefully in
turn the patella to its normal
the anterior surface of the fe[mur]
doing, a shearing force is app[lied]
patella which tears the trapped
the articular surface from the m[ain]
the patella The severed segm[ent]
comprises articular cartilage an[d]
subchondral bone the most com[mon]
the lesion is in the inferior medi[al]
of the articular surface Cases a[re]
which resulted from a direct b[low]
inner side of the patella forcing
The author has encountered 1 s[uch]
which a young Marine was str[uck]
medial side of the right knee wi[th]
of a rifle a complete lateral
ensued requiring manual reduc[tion]
general anesthesia Postoperat[ive]
genograms exhibited a loose b[ody]
lateral compartment Subseque[nt]
tion of the knee joint disclosed a
osteochondral body which fitte[d]
in a fresh defect noted on the
aspect of the articular surface
tella.

On occasion the aforementio[ned]
anism of indirect force may no[t]
a portion of the articular surf[ace]
patella instead trauma is inflic[ted]

region of sufficient *severity to produce* a local area of aseptic necrosis not unlike that encountered in osteochondritis dissecans Subsequently the affected portion of the articular surface becomes detached With healing of the original site the origin of the loose body is difficult to determine unless the undersurface of *the patella is visual* ized. If a healed defect is discernible in the cartilaginous surface, it is impossible to differentiate the lesion from one of healing following osteochondritis dissecans or one resulting from traumatic avulsion of car tilage and bone Coleman s series is of spe *cial interest because it emphasizes that a* recent osteochondral fracture may be super imposed upon the site of an old fracture He recorded that in one case the second injury scraped off a portion of the fibrocartilage which had partly repaired the defect in the patella.

CLINICAL FEATURES

As previously noted, usually the disorder is encountered in children and adolescents, but occasionally it occurs in young adults There is a history of twisting the knee, accompanied by an audible snap and severe pain in the joint. It may follow direct trauma to the inner aspect of the patella forcing it laterally into a position of dislocation. Also the lesion may be a complica *tion* of recurrent dislocation of the patella. Complete disability and marked swelling ensue After a period of several weeks the swelling subsides Upon walking, the pa tient may feel a "catch' in the knee joint, or the knee actually may lock Occasion ally the patient offers the information that the *loose body can be felt and displaced* manually As a rule in recent cases some diffuse tenderness is elicited by palpation over the medial expansion of the quadriceps muscle Invariably blood can be aspirated from the joint cavity In late cases the clinical course parallels that of osteochon dritis dissecans with a loose body in the joint.

ROENTGENOGRAPHIC FEATURES

Routine anteroposterior and lateral views may fail to disclose the defect in the articu lar surface of the patella, vertical or axial views usually disclose some irregularity of the articular cartilage The presence of a loose body is not detected by roentgenographic examination *in all instances*, par ticularly if the fragment consists entirely of cartilage The body may be depicted as a thin flake of bone (Fig. 185) Because the body comprises mostly cartilage the shadow it casts in roentgenograms is no indication as to its true size Such a shadow, together *with a hemarthrosis in young people*, should make one highly suspicious of an osteochondral fracture of the patella

TREATMENT

The joint cavity is exposed by a medial parapatellar incision The inside of the joint is inspected, and the loose body is removed. By rotating the patella outward on its longitudinal axis the entire articular surface comes into view The roughened irregular edges of the defect in the car tilaginous surface are made smooth with a scalpel In view of the observations that the mechanism of the lesion is primarily a subluxation or a dislocation of the patella, means to prevent a recurrence of the injury are deemed advisable Coleman recom *mends plication of the medial capsule as a* preventive measure.

CASE REPORT

The case of E K is typical of this entity A male 22 years old was admitted to the orthopedic service of the Jefferson Hospital with a painful swollen right knee joint. According to the patient's statement, 1 week *prior to* admission he slipped on a pebble and twisted the knee The joint immediately became swollen and painful and he was unable to straighten the knee completely Further questioning elicited that for the past 4 or 5 years the knee had a tendency to give way on sev eral occasions it had become markedly swollen Physical examination of the part revealed the presence of a hemarthrosis Pressure over the patella elicited severe pain, the knee could be



FIG 185 (*Left*) Case E. K. Note thin flake of bone in the lateral joint compartment. (*Center*) The body was removed and photographed note its size in relation to that depicted in the roentgenogram (*Right*) Case A. K. A loose body is seen in the infrapatellar region note the corresponding defect in the inferomedial aspect of the articular surface of the patella.

extended passively to 180° and in the relaxed position marked relaxation of the quadriceps apparatus was demonstrable Roentgenographic examination disclosed the presence of a thin flake of bone in the anterior aspect of the knee joint in the lateral compartment. A diagnosis of an osteochondral fracture was made (Fig 185)

On the following day the knee was exposed through a medial parapatellar incision Considerable blood was encountered in the joint cavity this was sucked out, and the joint was irrigated with a solution of normal saline A large loose body comprising mostly cartilage with a thin flake of bone was found lying free in the lateral compartment A corresponding defect was observed in the lower medial aspect of the articular surface of the patella. Figure 185 *center* depicts the loose body removed from the joint Note that no roentgenographic evidence of a defect is evident in the lateral view

FRACTURES OF TIBIAL TUBERCLE

Mechanism of Production and Clinical Features

This is a relatively rare lesion it is produced by excessive contraction of the quadriceps muscle with the knee in varying degrees of flexion It differs from avulsion of the patellar tendon in that only the central osseous portion of the insertion of this structure is avulsed the tendinous portion of the insertion which is attached to the lateral tuberosities of the tibia remains intact The difference in the severity of the two lesions is reflected in the clinical picture Although in general the signs and the symptoms of fracture of the tibial tubercle are similar to those of rupture of the patellar tendon the patient does not lose completely the power to extend the leg actively Also swelling and tenderness are localized directly over the tibial tubercle If the avulsed portion of the tubercle is large it may be readily palpable under the skin When the knee is flexed the fragment tends to be pulled upward On rare occasions the tibial tubercle may be fragmented by direct violence The author has encountered two such cases one was struck accidentally

on the anterior surface of the bony prominence by a steel bar, and the other fell from a height landing on the tubercle with the knee flexed. In these two instances active extension was not impaired but was painful. The lesions are depicted readily by roentgenograms

Treatment

Fracture of the tibial tubercle is treated by replacement and fixation of the fragment to its natural anatomic position After routine preparation of the skin the patellar tendon and the tubercle are exposed by a short lateral parapatellar incision which curves inward at the distal end of the tubercle crossing the anterior tibial crest. With the leg extended the fragments are replaced and maintained in position by sutures of chromic catgut or braided silk passing through the surrounding fibrous tissue and periosteum As a rule, sufficient soft tissue is available around the fracture site to anchor the fragment into place. If firmer fixation is desired, a screw or autogenous bone pegs may be employed, or the sutures may be passed through drill holes made below the crest of the tibia. The author never has found this to be necessary After the operation the limb is placed in a plaster cylinder extending from above the malleoli to the upper region of the thigh Rhythmical active contraction of the quadriceps may be started within 24 to 48 hours after the surgery Weight bearing is permitted at the end of 3 weeks and the cast is removed at the end of 8 weeks.

SEPARATION OF THE UPPER EPIPHYSIS OF THE TIBIA

This is an exceedingly rare lesion, it usually occurs in young children between the ages of 3 and 10 The natural configuration of the epiphysis (narrow and broad) and the broad lateral insertion of the patellar tendon into the tuberosities of the tibia are factors which protect the epiphysis from undue shearing forces The mechanism of separation of the epiphysis is similar to that recorded for ruptures of the patellar tendon namely, forceful contraction of the quadriceps muscle against resistance with the knee partially flexed The epiphysis as a whole usually is displaced forward and laterally Injury to the popliteal vessels and nerves may occur Displacement of the epiphysis is followed by active bleeding into the joint cavity, producing marked swelling of the joint, the capsular tissues are under severe tension All active and passive motion at the knee joint causes severe pain, the disability is complete The author has encountered one such case in a child 11 years old the injury was sustained when the patient jumped from a high fence Swelling was so severe that it obscured any alteration in the normal configuration of the knee joint Roentgenograms revealed that the epiphysis had slipped forward and slightly laterally approximately 1½ cm. No fracture was discernible in the portion of the epiphysis forming the tibial tubercle

Treatment

An attempt should be made to reduce the displacement as soon as possible after the injury In cases with marked swelling of the joint aspiration is indicated before reduction is attempted In the above case 200 cc. of blood was aspirated from the joint cavity With the patient under a general anesthesia reduction is achieved by traction on the lower leg in the long axis of the femur with the hip and the knee flexed from 30° to 45° While traction is being maintained by an assistant, the lateral displacement is corrected by making firm pressure on the lateral surface of the epiphysis with the heel of the hands Then the limb is immobilized in a plaster cylinder with the knee extended the cast is removed after 6 to 8 weeks and weight bearing is permitted Physical therapy is instituted to restore joint function

COMPLETE AVULSION OF THE EPIPHYSIS OF THE TIBIAL TUBERCLE

Avulsion of the tibial tubercle is not a common lesion The mechanism of production is similar to that of rupture of the patellar tendon and fracture of the tibial tubercle The signs and the symptoms noted in this disorder are in every respect like those encountered in the above lesions except that active extension is not lost completely The extent and the type of the avulsion is governed by the severity of the indirect force and the anatomic peculiarities of the proximal tibial epiphysis This growth center may be observed in one of two forms (1) the tibial tubercle may be continuous with the superior portion of the epiphysis appearing as a flat triangular prolongation of the main mass of the epiphysis on the anterior surface of the tibia or (2) the tibial tubercle may arise from a separate distinct center of ossification which unites at the fifteenth or the sixteenth year with the upper tibial epiphysis (Fig 186)

If the mechanism of excessive contraction of the quadriceps muscle with the knee flexed is applied to epiphyses in the first category the anterior prolongation of the tibial epiphysis may be pulled away from the anterior surface of the tibia without a break in its continuity or it may be detached completely from the main body of the epiphysis. If the same mechanism is applied to cases in the second category th small separate epiphysis of the tibial tubercle is torn away from its anchorage on the tibia In each case the clinical features are the same

Treatment

In cases exhibiting complete avulsion of the tibial tubercle replacement of the fragment by open operation is indicated The technic of the operation and the postoperative management are the same as those described for fractures of the tibial tuber



Fig 186 (*Left*) The tibial tubercle may be continuous with the superior portion of the epiphysis or (*Right*) it may arise from a separate center of ossification.

cle The use of internal fixation, such as bone pegs and screws, is rarely justified because the fragment can be anchored readily in its anatomic position by sutures of chromic catgut, cotton or silk passing through the surrounding soft tissues

OSGOOD SCHLATTER'S DISEASE

The etiologic factor responsible for this disorder is still a controversial subject Most observers favor the traumatic theory which is based on the observation that before the tibial tubercle unites with the shaft of the tibia it is a weak link in the extensor apparatus During adolescence, when more activity is expended than at any other period of life repeated stresses applied to the tibial tubercle produce minor avulsion of fragments of the tubercle or the entire ossification center Complete avulsion is prevented by the lateral insertion of the patellar tendon into the tibial tuberosities Although this is a plausible premise there are some features of the lesion which it does not explain, particularly the frequent bilateral occurrences In the same age period, similar changes may be noted at the site of insertion of the tendo achillis into the epiphysis of the os calcis and at the point of insertion of the peroneus brevis into the base of the fifth metatarsal bone and at the upper and the lower poles of the patella The last two sites often are referred to as Larsen Johansson disease

Recently Ferguson set forth an explanation of the condition which is attracting much attention He is of the opinion that Osgood-Schlatter's disease is not the result of minor avulsions of portions or of the whole tibial tubercle but that the bony changes noted are secondary to swelling hemorrhage and degenerative changes in the patellar tendon near its attachment these changes interfere with the circulation of the underlying bone and cause irregular ossification within it. The pathologic process is designated tenostosis it is encoun-



Fig 187 Case of bilateral Osgood Schlatter's disease

tered in mid adolescence and is caused by stress developed by rapid growth and expended on the patellar tendon near its attachment According to Ferguson the changes at the poles of the patella described by Larsen and Johansson are the result of this same mechanism The irregular ossification in the tibial tubercle appears some months after swelling of the tendon subsides, it tends to undergo repair after a few years Unfortunately, it often is interpreted erroneously as a fracture or an avulsion.

The author has encountered many cases which substantiate the aforementioned premise It is not uncommon to observe an adolescent with all the clinical features of Osgood-Schlatter's disease, yet the only positive finding is swelling of the patellar tendon being more pronounced near its insertion into the tibial tubercle. In these cases the roentgenograms fail to reveal any bone changes. However, later in the disease irregular ossification is demonstrable roentgenographically On several occasions the tendon was explored it was found to be thickened, edematous and markedly tense

Clinical Features

The condition is observed in adolescents boys are affected more frequently than girls Frequently, it is bilateral (Fig 187)



Fig 188 Irregular classification in tendon and irregularity of the tibial tubercle often encountered in late stages of Osgood Schlatter's disease.

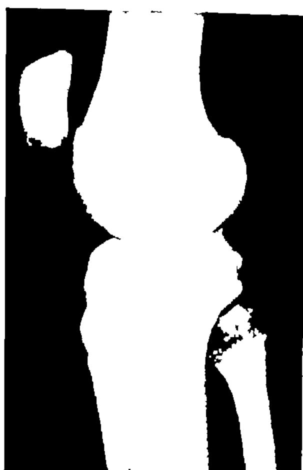


Fig 189 Islets of bone encountered in the patellar tendon close to the tibial tubercle. This patient gave a history from his adolescence consistent with Osgood-Schlatter's disease The islets of bone have failed to fuse with the tibia.

As a rule the onset is insidious the patient becomes aware of some pain and tenderness over the tibial tubercle The symptoms are accentuated by exercises or by direct trauma to the region A limp may be discernible and in more acute cases pain is felt when the leg is extended forcefully or against resistance Occasionally, the symptoms appear suddenly, usually after some form of strenuous activity Examination of the patient discloses varying degrees of swelling over the tibial tubercle and also some swelling and thickening of the distal end of the patellar tendon Pressure over the tubercle and the tendon near its insertion invariably elicits tenderness

Roentgenologic study in the early cases may reveal only a thickened patellar tendon anterior to the *tibial tubercle and swelling* of the overlying skin and subcutaneous tissue Later irregular ossification is observed in the tibial tubercle and some calcification may be demonstrable in the substance of the patellar tendon (Fig 188) Irregular ossification may exist without symptoms frequently it is encountered accidentally in roentgenograms of knees of adolescents However in these cases the tendon is normal the irregular ossification is the result of multiple ossification centers and not tenostosis

The duration of the condition varies it may persist from a few months to 2 or 3 years Invariably after all tenderness subsides *the affected* tubercle *remains* larger than normal Occasionally adults are en

countered who have some discomfort and disability of varying severity over the tibial tubercle. Roentgenograms may disclose islets of bone in the patellar tendon close to its insertion into the tibial tubercle and some irregular hypertrophy of this structure (Fig 189) These findings lead one to conclude that a condition comparable with Osgood Schlatter's disease existed during adolescence, and that the irregular islands of bone failed to fuse with the anterior surface of the tibia. Close interrogation of the patient may substantiate this conclusion.

Treatment

In most instances the symptoms are not of sufficient intensity to warrant immobilization of the limb or surgical intervention Most cases can be treated by avoiding sports when there is a flare up of symptoms or by a simple protective dressing over the tubercle when tenderness increases A piece of felt or sponge rubber with a hole in its center is placed over the tubercle and held by an elastic bandage The bandage should not be worn continuously The author has observed several cases in which the symptoms were of unusual severity All motions of the knee were acutely painful and the tubercle exhibited marked swelling and acute tenderness. In such cases bed rest until the acuteness of the symptoms subside is justifiable Also, immobilization in a plaster cylinder affords rapid relief Generally a period of 10 to 12 weeks of immobilization in a plaster cylinder effects a cure however, this is rarely indicated

As previously indicated, surgical management is rarely required However, cases of long duration and with symptoms of sufficient severity to interfere with the active life of the adolescent period may be relieved by surgical intervention Several methods may be employed (1) splitting

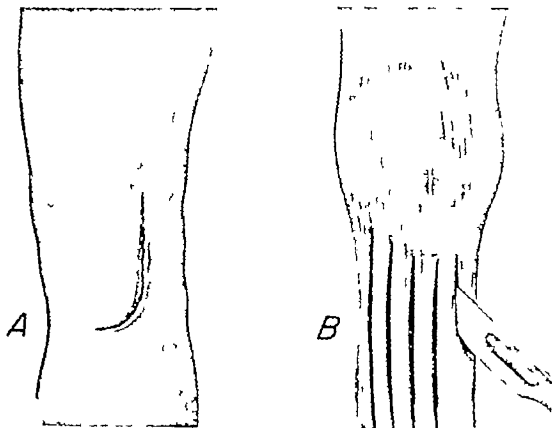


Fig 190 Method of making parallel longitudinal cuts in the patellar tendon (4 to 6 suffice) for resistant cases of Osgood Schlatter's disease The cuts traverse one half the thickness of the tendon.

the tendon (2) multiple drilling of the tibial tubercle (3) pegging with autog enous bone grafts and (4) excision of the loose fragments beneath or in the patellar tendon The author has utilized all these methods and is convinced that splitting the patellar tendon is the procedure of choice It is a simple operation and produces the desired results Drilling of the tubercle and insertion of autogenous bone pegs give the same immediate results but may prove to be harmful, especially if per formed before complete skeletal growth is attained premature fusion of the anterior portion of the tibial epiphysis may result in a deformity of the upper end of the tibia In adults with loose fragments beneath or in the patellar tendon simple excision suf fices

TECHNIC OF SPLITTING THE PATELLAR TENDON

The tendon and the tubercle are exposed by a J-shaped incision placed to one side of the mid line and extending from the level of the apex of the patella to the distal end of the tubercle (Fig. 190) From 4 to 6 parallel longitudinal cuts are made in the tendon penetrating approximately one half of its thickness At the termination of the operation a plaster cylinder is applied In asmuch as the continuity of the extensor mechanism is not interrupted, weight bear ing is allowed at the end of 7 to 10 days The cast is removed at the end of 3 weeks The same postoperative management is carried out for excision of loose fragments in adults

OSTEOCHONDRITIS OF THE POLES OF THE PATELLA (LARSEN JOHANSSON DISEASE)

Changes similar to those described in *Osgood Schlatter s disease are encountered* in the inferior pole of the patella and less frequently in the superior pole As previously *noted* Ferguson is of the opinion that *the alterations especially irregular* ossification, are secondary to swelling hem orrhage and degenerative changes in the patellar tendon (tenostosis) resulting *from* stress developed by rapid growth. Others believe the abnormalities are the result of the accumulative effect of repeated minor strains at weak points of attachment of the patellar tendon or if the superior pole is implicated at the attachments of the quad riceps tendon The lesion is often bilateral

The condition is observed in adolescents between the ages of 10 and 14 boys are affected more frequently than girls Gen erally the cardinal clinical features are pain, limp and soft tissue swelling localized over the involved pole of the patella Ex tension of the leg against resistance may produce pain Pressure over the affected regions invariably elicits tenderness. In creased activity accentuates the symptoms

In the early stages no bony changes *may be demonstrable by roentgenographic* study however swelling of the tendon is always discernible Later irregular ossifica tion appears near the insertion of the ten don into the pole of the patella, some calci fication may be present in the substance of the tendon (Fig 191)

TREATMENT

The average case is not of sufficient severity to demand immobilization of the limb Measures such as those described for mild cases of Osgood Schlatter s disease *suffice to carry the patient until the* symp toms subside More severe cases and those which fail to respond to simple measures may be treated by immobilizing the ex tremity in a plaster cylinder extending from above the malleoli to the upper region of the thigh A cure is usually effected in 6 to 8 weeks

CHONDROMALACIA PATELLAE

GENERAL CONSIDERATIONS

Chondromalacia patellae now i estab lished as a distinct clinical entity charac

terized by localized areas of degeneration of the articular cartilage of the patella. The severity of the degenerative alterations varies from softening and fibrillation of the cartilage to fissure formations, erosion of the cartilage and formation of bony excrescences To Budinger goes the credit for the first description of this lesion Other early observers to record the entity were Aleman and Konig the latter designated the disorder as chondromalacia patellae Although this entity is widely recognized abroad its true significance in disorders of the knee joint is not appreciated fully in this country However, the recent work of Soto-Hall has focused the attention of the American observers on the disorder

ETIOLOGY

It is generally conceded that repeated minor traumas or acute severe trauma are the etiologic factors responsible for chondromalacia of the patella in the majority of the cases Nevertheless many cases are encountered in which no evidence of minor or severe injuries can be elicited Hinricsson reviewed 604 cases he concluded that trauma was the initiating factor in only two thirds of the cases The investigations of other workers lead one to conclude that some individuals possess a natural predisposition for the development of the lesion also the functional mechanism of the knee joint is such that the articular cartilage of the patella and the opposing surface of the femur are subjected to undue stresses during normal joint function The author has observed a case of bilateral chondromalacia patellae in a child 15 years old trauma played no part in the etiology of this case It was interesting to note that the patient s mother was under treatment for the same disorder

Clinically close relationship exists between degenerative abnormalities of the patella and degenerative arthritis of the knee joint. Some observers are of the opinion that the lesions of the patella are precipitating factors in arthritis of the joint and if these are eliminated the joint may be spared, this observation has not been substantiated by the work of other investigators (Erb) It was recorded in Chapter 6, "Disorders of the Extensor Apparatus of the Knee Joint," that degenerative alterations of the osseous and the cartilaginous components of the knee joint and the synovialis occur naturally with advancing age, that they increase in severity from decade to decade and that the changes are more pronounced in those areas subject to the greatest stresses, such as the articular surface of the patella and the unprotected surfaces of the femoral and the tibial condyles

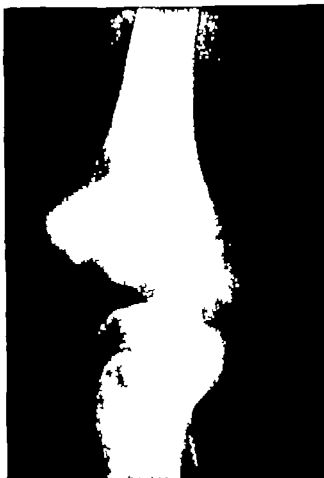


FIG 191 Osteochondritis of the inferior pole of the patella Note the irregularity of the tip of the bone.

Many other theories of the etiology of the conditions have been advanced. Sundt (1938) recorded that degenerative abnor

malities of the patella make up a constitutional disease and was of the opinion that the prime etiologic agent was injury to the synovial membrane. According to this worker the affected synovial membrane produced abnormal synovial fluid which was responsible for nutritional disturbances and degenerative changes in the articular cartilage. Hirsch (1944) noted some of the physiologic features of cartilage. He observed that cartilage had the faculty of adapting itself to increased pressures and still recovering its elasticity almost completely. This was possible only when the pressure per unit did not exceed the tensile strength of the cartilage and was sustained for only brief periods of time. If such pressures lasted for longer periods, impairment of elasticity resulted. He concluded that the normal elasticity of cartilage and its pumping action played a major role in the nutrition of the tissue, and that defective loading of the cartilage resulted in nutritional disturbances such as those seen in chondromalacia patellae. In contradiction to Hirsch's premise Cox (1945) expressed the belief that basic pathologic alterations occurred in the subchondral bone, the changes in the articular cartilage being secondary manifestations.

From the above brief survey it becomes apparent that considerable disagreement still prevails concerning the causative agents of chondromalacia of the patella. Nevertheless there is sufficient evidence to lead one to conclude that constitutional factors may play a part in the development of this disorder, that trauma is a common precipitating factor, and that natural wear, tear and aging also play a part in its development. The lesion also has been found to be associated with other derangements of the knee joint, such as bipartite patella, arthritis, osteochondritis and recurrent dislocation of the patella.

Incidence and Age

Chondromalacia patellae exists more frequently than is generally recognized. This is substantiated by the statistics recorded in some of the more recent investigations of this problem. Soto-Hall (1945) recorded that 18.5 per cent (12 cases) of 65 arthrotomies performed in a military hospital for chronic knee complaints exhibited implication of the patella. Cave, Rowe and Yee (1945) observed 9 cases in 124 arthrotomies in which degenerative alteration of the patella was the sole lesion responsible for the symptoms. Anderson (1944) was able to demonstrate the disorder in 10 cases of 50 arthrotomies.

The highest incidence is encountered in young adults. Hinricsson made a clinical diagnosis of the condition in a girl 10 years old. In Soto-Hall's series the average age was 29, the age of the oldest patient being 36.

Pathology

The early lesions usually involve the medial facet, and occasionally the lateral and central areas are implicated. In advanced cases all regions of the articular surface may exhibit some degree of involvement. The relationship of the articular surface of the patella to that of the opposing surface of the femur during flexion and extension of the knee joint affords an explanation for the frequent involvement of the medial facet of the patella. Wiberg demonstrated clearly that from the fully extended position when the knee is flexed from 20° to 50°, all the surface areas of the lateral facet and a small area of the medial facet articulate with the condyles of the femur. During this stage of flexion the central longitudinal ridge bears the greatest stress, which diminishes gradually as flexion is increased. At 90° flexion the pressure on the ridge is zero because the patella now settles into the intercondylar notch of the femur; contact between the patella and the condyles of the femur is maintained solely by the lateral and the medial facets. Of great significance is the

incongruity that exists between the convex surface of the medial facet of the patella and the convex surface of the medial fem oral condyle, their surfaces make some contact throughout the entire arc of motion from 90° to 180° This relationship is in contrast with that between the lateral facet and the lateral condyle of the femur their articular surfaces disclose good congruence during flexion and extension of the knee

The alterations observed in chondromalacia patellae are similar to the degenerative changes in cartilage described by Bennett and Bauer (1931), Keyes (1933) Parker, Keefer, Myers and Irwin (1934) Nichols and Richardson (1909) and the author (1950) Macroscopically, the normal bluish white, glistening resilient delicate articular cartilage is replaced by a yellowish opaque tissue which possesses little or no elasticity Simultaneously, small distinct furrows fibrillation and softening of the superficial layers of the cartilage appear As the lesion progresses the above alterations increase in severity one can readily demonstrate thinning, fibrillation of the cartilage and loss of compact tissue Small irregular scalloped ulcerated areas are discernible the subchondral bone may become exposed and thickened, assuming a polished surface In far advanced cases the entire articular surface of the patella may be implicated and the formation of irregular marginal excrescences may be a prominent feature This is true especially in chondromalacia patellae resulting from recurrent or permanent dislocations of the patella (Fig 192) Marginal proliferations or large pieces of degenerated cartilage may become detached and displaced into the joint cavity this is one source of loose bodies encountered in the knee joint

Generally varying degrees of implication of the synovialis are demonstrable. In early and mild cases the extent of involvement of the synovial membrane may be limited to a small area surrounding the periphery of the patella In more advanced cases the synovial lining of the entire suprapatellar pouch is thickened and reddened and may disclose diffuse villous formation simulating villonodular synovitis

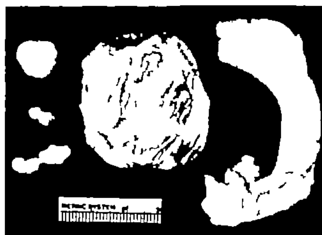


FIG 192 Advanced chondromalacia of the patella Note the furrows the fibrillation and the softening of the articular cartilage. Several loose bodies were found also in the joint. In addition a tear of the posterior horn of the medial meniscus is demonstrable. The patient was a male aged 24

As previously recorded, the articular surface of the femoral condyle opposing the affected medial facet may exhibit changes similar to those described in the patella Also, the femoral surface may be the site of the origin of loose bodies this is true especially in severe direct trauma to the patellofemoral joint. This lesion is comparable with an osteochondral fracture of the femoral condyle. Degenerative changes over the lateral femoral condyle may be present in cases of recurrent subluxation of the patella or in cases in which some weakness of the vastus medialis permits the vastus lateralis to draw the patella outward. Areas of degeneration in the femoral condyles opposing similar areas in the patella have been designated as 'mirror image" by Soto-Hall (Fig 193)

Tearing of the internal meniscus may be a concomitant pathologic finding The lesion may occur at the time of the initial trauma or subsequently The author has

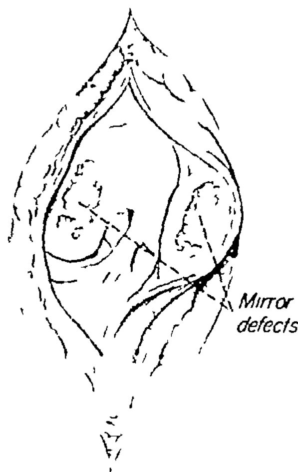


Fig 193 Schematic drawing showing degeneration in the femoral condyle opposing a similar area in the patella—"mirror image.

encountered 3 such cases all were young men in the armed forces (Fig 192)

Microscopic examination of representative patellae showing degenerative changes *of varying degrees of severity discloses the* progressive nature of the disorder Normally the superficial stratum of hyaline articular cartilage reveals many tightly packed spindle-shaped cartilage cells in a dense matrix Early lesions disclose *fibrillation of the superficial layers of the cartilaginous matrix* later *fibrillation extends* beyond the transitional and the calcified zones of cartilage to the subchondral bone thereby exposing it Cartilage cells in the vicinity of the fibrillated matrix demonstrate evidence of degeneration The cells are fewer in number and appear to be swollen and their nuclei stain abnormally The normal pattern of the cartilage cell in the various layers is lost those in the transitional and the calcified layers are arranged in groups of varying size The superficial layers of cartilage are worn away *gradually As the process in the cartilage* increases in magnitude alterations are demonstrable in the subchondral bone, the bony trabeculae become hypertrophied dense and compact and the marrow spaces are small and contain rich vascular tissue Endosteal cells (osteoblasts) are found in *great numbers lining the trabeculae* and exhibiting evidence of multiplication and proliferation of endosteal tissue This process increases the thickness of the trabeculae by adding newly formed osteoid tissue upon their surfaces The above connective tissue issues from the marrow spaces and covers *the denuded bony surface of the patella* also it gives rise to irregular tags of fibrous tissue which may undergo hypertrophy and even calcification

Clinical Features

Approximately three fourths of the *patients with chondromalacia of the patella* give a history of having sustained some form of direct violence to the anterior aspect of the knee joint In the remaining patients no history of injury is obtainable *hence one must conclude that other factors* must play a role in the development of this lesion Degenerative abnormalities of the patella with symptoms are frequent concomitant findings in recurrent and persistent dislocation of the patella In this group changes are found invariably in the *articular cartilage of the medial femoral* condyle

In the cases with a history of injury a period of total disability usually ensues immediately after the incident This is followed by almost complete recovery however the patient experiences some discom*fort in the affected knee particularly after*

increased activity After some months or even several years there is a gradual increase in the intensity of the symptoms and the degree of disability The course of the disorder may be hastened and the symptoms accentuated by additional traumata.

The earliest, most significant feature is crepitation in the patellofemoral joint however, it must be pointed out that chondromalacia of the patella may exist in the mild forms without crepitation Crepitation varies from a soft velvetlike sensation of roughness to a creaking crunching grating sound It is elicited best when the patient assumes the supine position with the hip and the knee flexed, then he extends and flexes the knee, holding the hip in a flexed position If the examiner places the palm of his hand on the patella while the patient executes the above movements, crepitation is readily palpable and frequently it is audible Crepitation often is very disconcerting to patients especially females One young lady avoided going up and down stairs because she sounded like a rusty hinge"

Pain is a variable symptom In early cases the patient is aware of a vague discomfort in the knee joint and has difficulty in trying to localize it. In more advanced cases pain is deep-seated and intense, being accentuated by activity and minimized by rest It is associated with a sense of weakness and instability in the joint Frequently the patient experiences sudden momentary locking of the joint these episodes may be followed by some pain and effusion into the joint True locking does not occur unless loose bodies or a torn meniscus is present As a rule, downward pressure made directly over the patella elicits varying intensities of pain particularly when the knee is slightly flexed (30° to 45°) With the knee extended fully and the quadriceps muscle relaxed exquisite pain may be produced by making firm pressure on the patella and thus forcing it against the medial femoral condyle Also, with the knee in the same position and maintaining gentle downward pressure on the patella the bone can be displaced up and down or from side to side, producing varying grades of palpable crepitation Invariably, this last maneuver is associated with pain

Severe lesions of long duration may reveal some pericapsular thickening due to hypertrophy of the synovial lining and varying amounts of synovial effusion Also, swelling may be demonstrable in the subpatellar region, resulting from hypertrophy of the infrapatellar fat pad Some atrophy of the quadriceps muscle may be discernible

Roentgenographic Features

Roentgenograms are of little diagnostic value in this area, this is true also of the special projections that may be made such as axial views However, in far advanced lesions axial views may reveal some irregularity and thinning of the articular cartilage of the patella. Axial views are of special value in determining the course of the patella in relation to the femoral condyles during varying degrees of flexion of the knee joint.

Treatment

Conservative measures are reserved for the group of patients in which the symptoms are mild and the disability is minimal In this group the degenerative changes in the patella are in the earliest stage of development and are more or less quiescent Much can be achieved if the patient is made to move within the capacity of his knee joint, avoiding undue stress to the patellofemoral articulation and protecting it from additional injuries He should not participate in strenuous activities More important is a regimen of progressive exercises designed to restore the quadriceps mechanism to optimum power and function By attaining this goal the gliding mechanism of the patella functions without

inflicting undue stresses on the femoral condyles

Surgical intervention is the treatment of choice in cases in which the symptoms are constant severe and markedly disabling Several operative procedures have been designed to meet this problem They are (1) resection of the degenerated cartilage (2) total resection of the articular surface of the patella and (3) patellectomy The author has employed all these methods from time to time A survey of the long term end results (1 to 10 years) of 18 cases of chondromalacia of the patella reveals that complete resection of the articular surface of the patella gives the highest incidence of poor results in fact in this series the incidence of poor results in 8 cases was 100 per cent *The best results were obtained* in the group treated by resection of the deteriorated cartilage Patellectomy never should be performed in cases in which the degenerative changes are not severe and are limited to the articular surface of the patella It is reserved for cases with far advanced involvement of the patellar articular surface or of the entire patellofemoral joint and for cases with pronounced hypertrophic osteoarthritic changes of all the components of the knee joint In cases showing severe implication of the synovial membrane the author does not hesitate to perform a synovectomy in addition to a patellectomy The choice of operation often is determined by the severity of the pathologic processes observed after the joint is exposed The author feels that in the future *a patellar prosthesis such as the one designed* by D C McKeever will supplant all other operative procedures (Fig 194)

TECHNIC OF PARTIAL CHONDRECTOMY

Adequate exposure of the joint is essential in order to evaluate the extent of the disorder and the absence or the presence of *concomitant lesions such as loose bodies* or a torn meniscus (Fig 195) A median parapatellar incision provides this exposure moreover in cases with increased laxity of the medial patellar retinaculum and the capsule this approach facilitates operative measures such as plicating or reefing to correct this defect in the affected structures

The patella is rotated outward on its vertical axis thereby exposing the articular

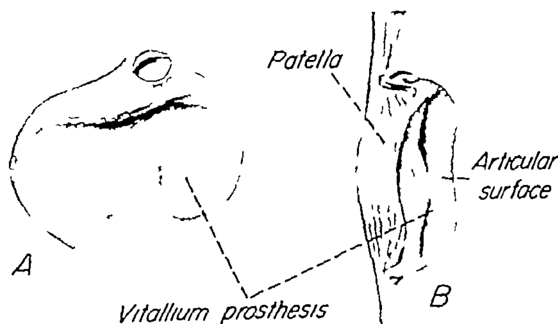


Fig 194 Patellar prosthesis designed by D C McKeever It is of special value in advanced cases of chondromalacia patellae

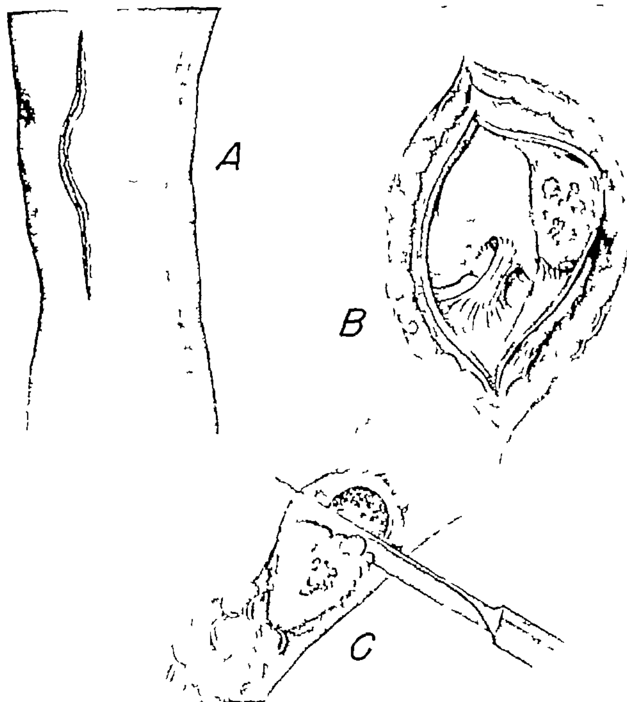


Fig 195 Method of shaving off layers of defective articular cartilage from the surface of the patella (partial chondrectomy)

surface The degenerated area in the cartilage is identified and with a scalpel the soft fibrillated tissue is removed in thin layers until only a thin smooth transparent stratum of cartilage remains If the opposing articular surface of the femoral condyle is involved, it is treated in the same manner

Chondromalacia patellae observed in cases of recurrent dislocation of the patella is treated in the same fashion described above except that operative measures are added to stabilize the patella these have been described in a previous section, "Recurrent Dislocation of the Patella' (see pp 187 196)

ACUTE OSTEOMYELITIS OF THE PATELLA

Hematogenous osteomyelitis of the patella is an exceedingly rare lesion. A survey of the literature reveals only the report of isolated cases. The author has encountered 2 cases, both in children under the age of 10. It was interesting to note that in both the systemic reaction was relatively mild. Failure to recognize the entity in its early stages may be followed by rupture of

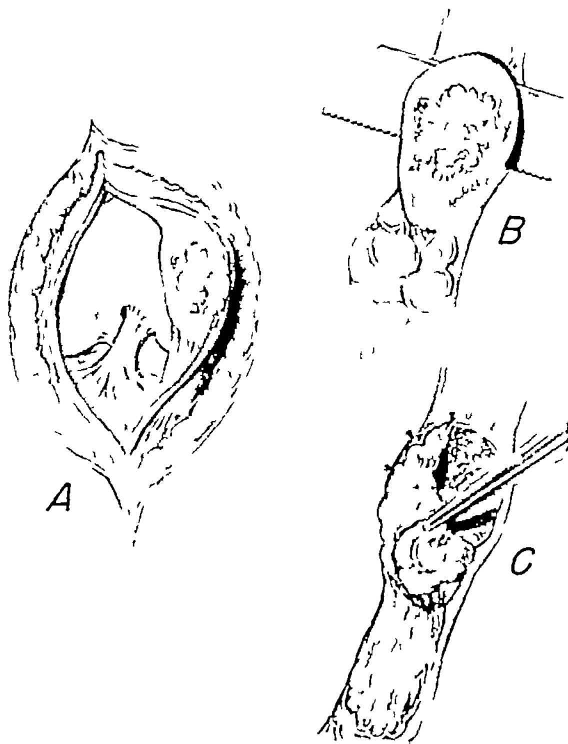


Fig. 196. Technic of excision of the articular surface of the patella. The raw surface is covered with fat.





FIG 197 (A, *Left*) Case A. W, 8 years old. Note diffuse swelling of the left knee joint resulting from osteomyelitis of the patella. A patellectomy and a synovectomy were done in this case. (B, *Right*) Roentgenogram of the same case. Observe fragmentation of the patella and distention and thickening of the capsule.

the local infected area into the joint cavity producing a pyarthrosis In both instances a fulminating response was noted in the synovial membrane of the knee joint, large amounts of synovial fluid formed distending the capsule A relatively wide arc of free painless motion was demonstrable in both cases there was 20 restriction of flexion in one and 35° in the other case Aspirations of the joint revealed a yellowish flaky turbid fluid in one patient s knee and thick yellowish mucoid material in the other s Cultures of the synovial fluids in each case showed no growth of organisms It must be admitted that both patients had received large dosages of antibiotics before the joints were aspirated this may explain the negative cultures However cultures made from foci within the substance of the patellae after their removal yielded *Staphylococcus aureus*

The patellae were excised in toto, in addition a synovectomy was done in each case Only the synovial lining of the suprapatellar pouch and the anteromedial and the anterolateral recesses of the joint was removed the synovial membrane in the posterior aspect of the joints was not excised Both cases made a prompt and uneventful recovery there has been no recurrence Over 18 months have elapsed since the last operation and an acceptable range of motion has been attained in each instance

Case A W., an 8 year-old Negro boy complaining of pain and swelling in the left knee joint was admitted to the hospital One and one half months prior to his admission he fell and scraped the skin overlying the knee cap the knee became slightly swollen This subsided gradually and except for some stiffness within 2 weeks the patient had no pain and engaged in all activities. Again he fell about 3 weeks after the first injury once more injuring the same knee. Within a few days the knee became hot, swollen and painful, he

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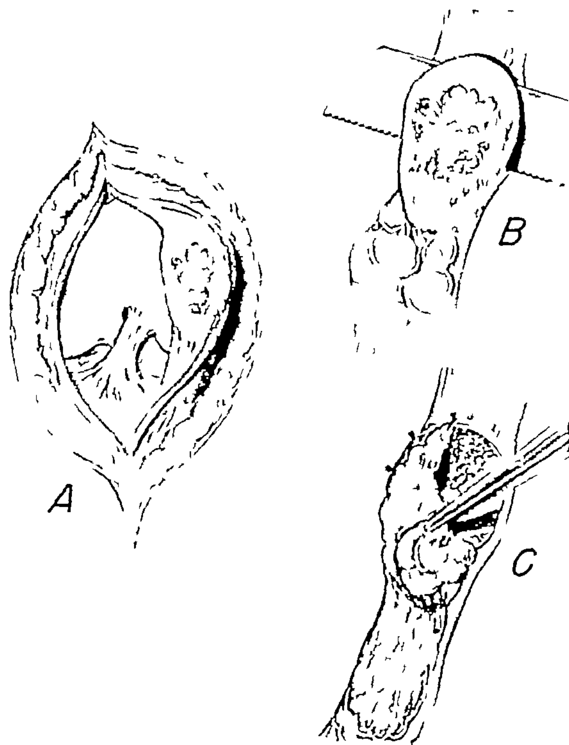


Fig 196 Technic of excision of the articular surface of the patella The raw surface is covered with fat





FIG 197 (A, *Left*) Case A W, 8 years old Note diffuse swelling of the left knee joint, resulting from osteomyelitis of the patella A patellectomy and a synovectomy were done in this case. (B *Right*) Roentgenogram of the same case Observe fragmentation of the patella and distention and thickening of the capsule.

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was unable to bear weight on the affected limb

On admission the patient did not appear to be toxic or dehydrated The knee was markedly swollen some restriction of flexion was discernible (Fig 197 A) Pressure over the patella elicited severe tenderness. Aspiration of the joint yielded 150 cc of a turbid yellow fluid after aspiration the patient had less discomfort and flexed and extended the knee with ease Smears and cultures of the fluid proved to be negative

Further studies within the next few days disclosed a low septic temperature range an increased sedimentation rate and a high leukocyte count (16,000) Roentgenographic studies of the knee revealed the joint capsule to be markedly distended and the patella presented a moth-eaten appearance from irregular fragmentation (Fig 197 B) A diag



Fig 197 (C *Top*) Patella of same case On the right the superior surface is depicted on the left the inferior or articular surface Note the perforation of the articular cartilage in the latter (D *Bottom*) Roentgenograms taken 18 months postoperatively Motion in the affected knee was possible from 80 to 180 no recurrences of the infectious process had occurred

nosis of osteomyelitis of the patella was made. The limb was immobilized on a posterior splint, and continuous hot fomentations were applied, the knee was aspirated on two more occasions. Intensive antibiotic therapy also was instituted. In spite of these measures no local change in the knee joint occurred however, the patient's general condition improved although he maintained at all times a slightly elevated temperature Two weeks after admission to the hospital a decision in favor of surgical intervention was made

The knee joint was exposed through a median parapatellar incision, thick turbid fluid was encountered when the joint capsule was opened. Both surfaces of the patella had large cavitations containing necrotic material severe cavitations on the anterior surface had extended to and perforated the articular layer of cartilage (Fig 197 C) The synovial lining was thickened and red and formed numerous folds and villi it was studded with flakes of fibrin The patella was excised in toto and a total synovectomy was performed The joint cavity was flushed with a solution of normal saline and closed in layers without drainage. Penicillin was instilled into the joint, and a posterior splint was applied. Systemic antibiotic therapy was continued for 2 more weeks in this period the temperature returned to normal. Some postoperative swelling occurred this subsided gradually Quadriceps exercises were commenced on the tenth postoperative day, and weight bearing on crutches 2 weeks later When the patient was last examined (18 months postoperatively) no swelling was demonstrable and motion was possible from 180° to 80° the quadriceps muscle still showed slight atrophy when compared with the normal side Roentgenographic studies disclosed a normal joint space, healthy bone trabeculae and no evidence of reformation of the patella (Fig 197 D)

Case M V a white boy aged 9 years injured the right knee while playing football The following day the knee became swollen hot and painful He was put to bed, and cold

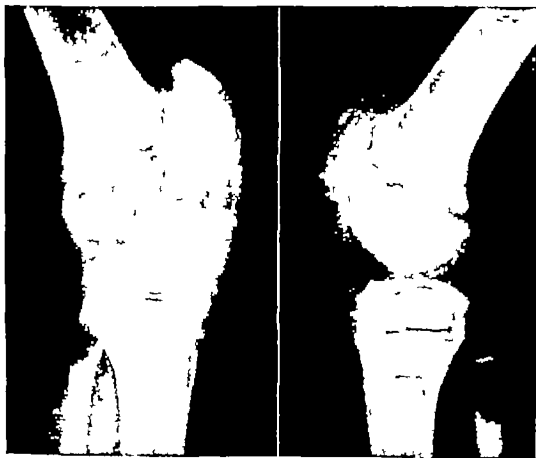


FIG 198 (*Left*) Observe the advanced fragmentation of the patella and the distention of the capsule Case M V male, 9 years old osteomyelitis of the patella. (*Right*) Roentgenograms of same case 6 months postoperatively Two years later the range of motion was from 70 to 180°

applications were applied to the part. After a week of bed rest in spite of some pain and swelling he was allowed to bear weight. The knee again became very painful distended and hot A diagnosis of a suppurative knee joint was made by the attending physician and he was referred to the hospital for further care

Upon admission 10 days after the onset of symptoms the patient exhibited a markedly swollen hot and tender knee joint. Although some motion was possible without precipitating pain extension beyond 160 and flexion beyond 90° could not be achieved actively or passively The temperature was 102 5° F Aspiration yielded a slightly turbid yellowish fluid which showed no organisms on smears or growth on cultures Roentgenographic studies disclosed pronounced distention of the capsule and fragmentation of the patella (Fig 198) A diagnosis of osteomyelitis of the patella was made The limb was elevated and immobilized by 10 pounds of skin traction hot compresses were applied and antibiotic medication was commenced. The patient continued to run a septic course without local improvement. Aspiration was performed on two other occasions and each time copious amounts of thick mucoid material was withdrawn

Ten days after admission the anterior surface of the patella was explored through a short curved incision along its medial border When the skin was reflected two cavitations were encountered in the proximal portion of bone which extended directly into the joint cavity The incision was converted into a median parapatellar incision and the entire joint cavity was exposed

As in Case A W the patella was perforated by several cavities which contained pus and other tissue debris its upper one half was broken up into three irregular fragments lying loose in the soft tissue bed of the extensor tendon. The synovialis was almost purple in color and thickened to such a degree that the entire suprapatellar region was obliterated by this edematous tissue

A combined patellectomy and synovectomy was performed and after flushing the wound with normal saline solution it was closed loosely without drainage Penicillin (250 units per cc 10 cc) was instilled into the joint cavity and the limb was immobilized on a posterior plint Postoperative management was identical with that described in Case A W This patient attained an excellent result Two years later he had power of extension to 180 and flexion was possible to 70° No recurrence had occurred and no evidence of a patella was yet demonstrable clinically or roentgenographically

RESTORATION OF NORMAL QUADRICEPS FUNCTION

General Considerations

Both internists and surgeons are keenly aware of the rapid deterioration of the quadriceps muscle following systemic diseases and diseases and injuries affecting the knee joint In spite of this knowledge there is a serious lack of understanding in the profession as a whole of the basic principles governing restoration of the extensor mechanism to normalcy Too many physicians are prone to delegate the responsibility of redevelopment of this important apparatus to a technician in the department of physical medicine without designating specific instruction designed to achieve maximum function in the shortest time This is a serious trend because it delays prompt restoration of function and it predisposes the patient to unfavorable sequelae which may progress to irreversible stages

In order to prescribe an adequate program for redevelopment of the quadriceps apparatus one must know the anatomic and functional peculiarities of this mechanism. It was pointed out in Chapter 4 "Mechanics of the Knee Joint" that from an anatomic viewpoint the quadriceps comprises the rectus femoris and the three vasti muscles Functionally the components of the muscle mass differ the rectus femoris working alone is unable to achieve complete extension of the leg but the vasti working as a unit readily perform this function The last 15 of motion are accomplished by the vastus medialis which is the most powerful of the vasti Although the vastus medialis contracts throughout the entire range of extension its most powerful contractions occur toward the end of the movement forcing the leg in the fully extended position This can be demonstrated readily on oneself If one assumes a sitting position holds the hip

in a fixed position of flexion and then extends the leg, one will note that all the components of the quadriceps contract throughout the entire arc of extension, however, contraction in the rectus femoris and the vasti lateralis and intermedius is more pronounced than in the vastus medialis in the beginning of the movement This difference in power of contraction (evidenced by the size and the firmness of the individual muscle masses) is demonstrable up to approximately 165° of extension, then powerful contraction of the vastus medialis ensues, completing the last 15° of extension If the test described is performed against resistance e g, a 5 pound weight on the dorsum of the foot, the aforementioned observations are discernible more readily than when the quadriceps works without added resistance

Study of the comparative anatomy of the knee joint reveals that the size and the function of the vastus medialis in man are recent acquisitions and they parallel in development the assumption by man of the erect position and the development of a free bipedal gait The erect posture in man is made possible by the faculties of the quadriceps especially of the vastus medialis to produce powerful and complete extension of the leg on the thigh, to stabilize the knee joint during varying degrees of flexion and to maintain equilibrium These functions have been acquired recently by the quadriceps which is designed primarily to motorize the knee in the plantigrade position That the functions of the quadriceps are late acquisitions in man s progress from a plantigrade to an orthograde status is reflected in the ease with which the intrinsic mechanism of this muscle mass is unbalanced by trivial injuries diseases interfering with normal function of the knee joint or systemic diseases enforcing a period of disuse upon the muscle This disorder is manifested in the progressive loss of muscle volume the diminishing power of contraction and the disorientation of the muscle mass. The severity of the derangement varies In advanced cases the clinical features are similar to flaccid paralysis of the muscle An inadequate quadriceps or 'quadriceps insufficiency," produces a sense of instability in the knee joint. It fails to provide sufficient stability and equilibrium particularly when the patient descends stairs the knee tends to buckle or give way The vastus medialis is by far the most important component of the quadriceps in the execution of complete extension and in the maintenance of stability and equilibrium The derangements resulting from wasting of the muscle impose

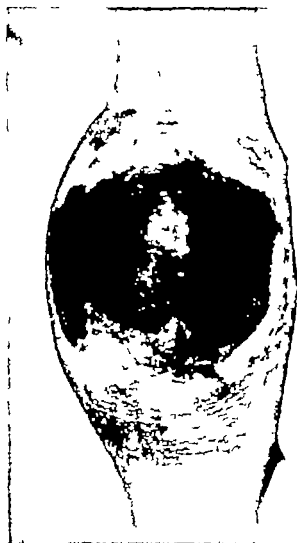


Fig. 199 Massive hemorrhage in the knee joint of a hemophiliac, resulting in total necrosis of the overlying tissues and the vastus medialis muscle

undue strains on the ligaments the capsule and the synovial lining of the knee joint this in turn is responsible for synovial effusion, relaxation of the aforementioned supporting elements of the joint and further increase in disability The disorder increases progressively and can be terminated only when the quadriceps muscle particularly the vastus medialis has recovered sufficiently in volume and power to interrupt the cycle Permanent loss of full extension regardless of the causative factor is responsible for profound disability This is encountered occasionally in advanced wasting or destruction of the vastus medialis A case in point is that of a boy 13 years old The patient a hemophiliac sustained a massive hemorrhage in the left knee joint following a trivial injury In spite of active therapy the anterior capsule of the joint the overlying skin and the vastus medialis underwent total necrosis necessitating wide excision of the necrotic tissue (Fig 199) The defect was covered with a skin graft (Fig 200 *Left*) Considering the severity of the complication the end result must be considered to be excellent however the loss of the greater portion of the vastus medialis (unfortunately this included the important distal insertion of the muscle) has resulted in a loss of the last 15 of extension (Fig 200 *Right*) which predisposes the patient to repeated trauma Now he is denied the protective and the stabilizing features provided by the vastus medialis This has added greatly to the difficulties of management of the patient

PHYSICAL PROPERTIES OF MUSCLE

Comprehension of the properties of muscles which govern their functional mechanism is essential in order to administer a program of muscle redevelopment intelligently Nicoll has set forth in a masterly manner the features peculiar to muscle and has emphasized the significance of each one These comprise (1) power of contraction (2) velocity or speed of contraction (3) co-ordination and (4) endurance

Muscle Power

Power or strength of normal muscle can be preserved only by unrestricted activity any factor which inhibits muscle function in the slightest degree initiates diminution of power Immobilization of an extremity exemplifies this point If exercises are performed while a limb is in plaster regardless



Fig 200 (*Left*) Following excision of soft tissue the defect was covered by a split thickness graft. (*Right*) Note the lack of complete extension resulting from loss of the insertion of the vastus medialis muscle

of the intensity of the exercises some loss of muscle power and volume ensues It is an established fact in the physiology of muscle that each contractile unit contracts to its fullest extent or not at all (Sherrington) Hence, the adaptation of power output to load can be achieved only by varying the number of units working at any given moment. Also the efficiency of a muscle fiber is influenced by the extent to which it is stretched, as it shortens it becomes mechanically less efficient. Nicoll further pointed out that the accurate method of measuring power of muscle is to determine the maximum load at which the muscle is capable of working It becomes apparent that diminished power or strength and loss of volume of muscle following immobilization of a limb in plaster result from failure of all the contractile units to function efficiently Exercises performed with the limb in plaster call on a limited number of units to work these do not perform at their maximum efficiency because the position of the limb places the muscle fiber in a relatively shortened position

The above observations are of special significance in the choice of exercises designed to restore volume and tone. It becomes obvious that graduated resistant exercises are mandatory in order to attain this goal This is substantiated by the massive hypertrophy of certain groups of muscle used against resistance in certain occupations and athletic activities In these cases unusual development occurs in order to meet the functional demands made on the muscle groups over a long period As will be discussed more fully subsequently some workers have demonstrated that high resistance exercises tend to develop power while low resistance exercises develop endurance which is another property of muscle not related to power

Velocity and Speed of Contraction

This property of muscle together with co-ordination permits one to perform work requiring "agility dexterity" and "timing" It is in part inherent and in part acquired Together with power, it protects joints and ligaments from injury, this is readily demonstrable in the knee joint. Stretching of the tibial collateral ligament initiates a stretch reflex to which the vastus medialis responds by rapid powerful contraction It becomes apparent that if this reflex mechanism is executed with great speed on the part of the vastus medialis the joint and its ligaments are protected from injury the time period may be a matter of split seconds. Redevelopment of velocity, or speed of contraction of muscles should be an essential facet of every program designed to restore atrophied and wasted muscles to normalcy this can be achieved readily by intensive training

Co-ordination

This highly specialized property of muscle concerns the synergic and antagonistic action of a muscle as opposed to its function as a prime mover Unfortunately, it tends to disappear rapidly during periods of inactivity and immobilization However, this feature can be minimized by exercises hence much is to be gained by insisting that exercises be performed during a period of immobilization in plaster and that general exercises be maintained by the recumbent patient. By such a regimen the proprioceptive mechanisms and other related complicated reflexes are in constant training As previously noted, co-ordination, together with velocity or speed of contraction, is the basis for that important quality, "timing" it also can be regained and developed to a high degree by training The importance of adequate consideration of "co-ordination in outlining a plan for muscle redevelopment becomes obvious.

Endurance

This property is in no way related to power of muscle essentially, it is the ability of muscles to continue "working at a high efficiency over a prolonged period' It is not concerned with bulk which is de

pendent on the number of working contractile units in muscle rather it depends upon the respiratory and circulatory efficiency in muscles Work produces waste products in muscle endurance is associated with the ability of muscle to eliminate waste products *sufficiently rapidly to prevent fatigue* Many workers and more recently Delorme have demonstrated that muscles subjected to low resistance high repetition exercises develop endurance but not power On the other hand high resistance low repetition exercises develop power and bulk but not endurance The logical approach to this problem is first to restore power to a weakened muscle and then develop endurance

PRINCIPLES OF EXERCISES

As indicated by Nicoll in 1943 exercises in a well regulated program must be (1) both focal and general (2) administered with careful consideration of dosage (3) rhythmic in regard to contraction and relaxation (4) progressive in range power and time and (5) variable in form.

Focal and General Exercises

The goal of specific or focal exercises is to concentrate attention on a particular muscle or group of muscles for the purpose of selective development such exercises require the affected muscle to work as a prime mover This is an essential feature in restoration of the patient as a whole because if *neglected* the patient shows a natural tendency to avoid movements producing pain he develops compensatory or "trick" movements replacing normal functional movement In *so doing* weakened or *painful* muscles are disregarded Focal exercises together with general exercises properly executed expedite restoration of muscles to normalcy and facilitate attainment of functional movement

When applying the above principle to the *quadriceps one must be familiar* with the intricate mechanism of the muscle mass It is not enough to concentrate on the redevelopment of the quadriceps muscle per se rather it is more important to design exercises to restore the vastus medialis to full power It must be emphasized that the vastus medialis is endowed with a selective *action of its own* Although it works in union with the rectus femoris and the other two vasti muscles throughout the entire range when working against resistance it is solely responsible for the last 15 of extension and under normal conditions comes forcefully into play only within this small range It becomes obvious that exercises failing to take into consideration the small but very important last 15° of extension neglect the vastus medialis totally Unfortunately many exercises in common use fall into this category such as cycling running and ascending and descending stairs Patients may learn to perform these exercises without extending the knee completely hence the vastus medialis is cut out of the exercises Moreover it is impossible to exercise the vastus medialis adequately while the limb is in plaster with the knee flexed more than 15° this results in progressive wasting of the muscle Nicoll considered the selective exercises of the vastus medialis of sufficient importance to suggest that the term 'quadriceps drill" be abolished and that vastus internus drill" be instituted

Selective exercises are evolved primarily to develop an affected muscle as a prime mover however this function alone is not sufficient to restore complete functional movement This can be achieved only by development of all functions of muscle In other words the implicated muscle must *function again as a fixator a synergist and* an antagonist in addition to being a prime mover All functions must be integrated into a smooth working unit By so doing the muscle becomes once more a functional unit in the entire locomotor system This goal is attained best by general exercises designed to incorporate the injured muscle in the functional mechanism of the body as a

whole. Occupational therapy and group activities provide general exercises for this purpose, also, these methods may include focal exercises.

Dosage

It is common knowledge that weakened and wasted muscles may be injured seriously by overdose of exercises. This may be produced by forcing the muscles to work against loads beyond their optimum efficiency and by permitting the muscles to act for relatively long periods without sufficient rests The demands (in stress and time) made on an injured muscle should be in proportion to the patient s strength the weaker the muscle, the less should be the demands

Abuse of the above principle is observed too often in the management of the quadriceps muscle. Excessive demands made on this muscle are reflected in the unfavorable sequelae noted in the knee joint Weight bearing before the quadriceps has recovered sufficiently to stabilize and protect the knee joint results in repeated strains of the capsular tissues the synovial lining and the ligamentous apparatus This in turn is followed by a synovial effusion pain and instability of the joint Such a sequence of events induces further atrophy and wasting of the quadriceps It becomes apparent that weight bearing should be allowed only when the quadriceps particularly the vastus medialis has attained sufficient strength to perform its functions without undue stress and fatigue. By adhering to this principle functional recovery of the muscle and the knee joint is expedited and untoward complications are avoided

Rhythm

Muscle tissue functions at optimum efficiency when its nutritional demands are satisfied and all waste products are removed This is the basis for complete relaxation of muscle for a sufficient period after each contraction During this period the muscle fibers are replenished with blood containing all the nutritional elements, and waste products are eliminated, the muscle is now ready for another contraction In injured and atrophic muscles the blood and the lymphatic circulation are impaired seriously, this leads to varying degrees of intramural and interstitial fibrosis which further increase the circulatory embarrassment and impede removal of harmful end products of muscle metabolism It becomes apparent that both specific and general exercises must be evolved which will permit a period of relaxation of sufficient duration to allow maximum restoration of the circulation in an affected muscle and permit sufficient time to clear the muscle of waste products It has been demonstrated many times clinically that far advanced fibrosis and deterioration of the quadriceps can be overcome relatively rapidly by exercising the muscle with a well regulated program of exercises graduated progressively in intensity but with an adequate rest period between each contraction and between each series of exercises Exercises characterized by sustained contractions are harmful and fail to produce the desired results

Progression

The principle of progression is one of the most important facets of any correctly designed program of exercises Progression should include contraction of a muscle against gradually increasing stresses through gradually increasing ranges of movement and over gradually increasing periods of time " Progression must embody power endurance and range of movement of these power is the most important Clinical experience reveals that once power of muscle approaches normal endurance and range of movement are achieved readily The work of Delorme substantiates this observation this investigation will be discussed further under 'Quadriceps Exercises' It may be exceedingly difficult to institute a plan of progressive exercises in

cases of profound atrophy of the quadriceps. The patient's muscle may be disassociated completely from the patient's control. In such cases contraction may be induced by faradic stimulation. After voluntary contraction is resumed the principle of progression outlined above may be applied. In the course of developing power of the quadriceps particular care must be taken to avoid violation of the principle of overdosage.

VARIATIONS

In order to hold the patient's interest and stimulate him to greater effort the exercises must vary in form. A routine comprising the same exercises without variations performed every day tends to become boring and the patient loses enthusiasm. Occupational therapy and group exercises provide means of variations of a monotonous routine; however, one must not lose sight of the goal to be achieved when these methods are employed. On the other hand, if properly selected, the methods provide both focal and general exercises and tend to decrease the patient's mental tension and apprehension.

QUADRICEPS EXERCISES

Essentially the types of quadriceps exercises in common use fall into two categories: (1) nonweight bearing exercises and (2) weight bearing exercises. Both types play an important role in rehabilitation of the quadriceps provided that they are instituted at the proper time and are performed with close adherence to the principles governing exercise therapy previously discussed.

Both forms of exercises are capable of increasing power; however, weight bearing exercises often are accompanied by pain, synovial effusion and instability of the knee joint; these features may be accentuated by the exercises. This is not true of nonweight bearing exercises. Moreover, if the aforementioned associated features exist, the nonweight bearing form of exercise therapy tends to alleviate them. As previously noted, the quadriceps apparatus is an important stabilizer of the knee joint, protecting it from undue stresses and strains. Following injury, disease or operation it frequently becomes weakened, wasted and atrophic; hence it loses its protective quality and the knee is predisposed to repeated strains, resulting in capsular and synovial thickening, synovial effusion, pain and further instability. This vicious cycle can be interrupted only by returning power to the quadriceps apparatus, particularly the vastus medialis.

Weight bearing exercises performed in cases of instability of the knee following meniscectomy often increase the laxity of the capsular and the ligamentous apparatus, permitting repeated strains which in turn produce traumatic synovitis. Such exercises fail to restore quickly sufficient power in the quadriceps to protect it from further injuries; instead, they are performed by twisting and stretching movements which inflict additional trauma on a relaxed joint. The cruciate and the lateral collateral ligaments and the capsule of the joint with its numerous reinforcing fibrous expansions are not capable of providing sufficient stability to the joint without the aid of a strong quadriceps muscle. Weight bearing before normal power is regained in the quadriceps imposes undue harmful stresses on the aforementioned tissues.

Nonweight bearing exercises strive to redevelop quadriceps power to a high level of efficiency, thereby restoring the protective mechanism of this muscle which precludes additional injuries to the capsule, the ligaments and the synovialis of the knee joint. In fact, swelling of tissues, synovial effusion and pain often disappear rapidly in nonweight bearing exercises. Delorme has noted this observation in his investigation, and it has been observed many times by the author. Nonweight bearing exercises can be performed without imposing injurious strains on the soft tissue elements of the articulation, and the knee is not under the

strain of the body weight. All these factors favor a rapid return to normalcy of the quadriceps and of the functional mechanism of the knee joint

EXERCISES TO RESTORE POWER AND ENDURANCE

Restoration of power in a weakened quadriceps should be the first concern of the surgeon Most of the conventional exercises fail to attain this requisite rather, they are designed primarily to develop endurance and normal joint motion It is erroneous to endeavor to restore increasing ranges of movement in the knee and greater endurance in the quadriceps without first developing power Clinical experience discloses that wide ranges of motion in the knee without adequate power supplied by the muscular apparatus results in a weakened unstable joint which tends constantly to give way and to buckle.

Power and endurance are two distinct characteristics of muscle and they are not restored to normalcy by the same group of exercises As pointed out by many observers and particularly by Delorme, failure to discriminate between endurance building and power building exercises has resulted in the high percentage of poor results observed following injuries or diseases of the knee joint. Unfortunately, most of the current methods evolved to redevelop the quadriceps employ exercises which primarily develop endurance and not power Exercises such as stair-climbing bicycling and walking are of this nature

On the other hand power building exercises are not capable of producing endurance Endurance building exercises are very important in the over-all program of physical therapy however they should not be instituted until the quadriceps has regained its strength and is capable of protecting the knee joint It is interesting to note that with the attainment of power the range of motion in the knee increases rapidly This is true in all instances except in cases in which improvement is impeded by some mechanical barrier

The author is in complete agreement with the concepts of Delorme and has confirmed his observations many times In the past 5 years a method of rehabilitation of the extensor apparatus has been evolved based on the principles set forth by Delorme, it has proved to be most satisfactory in all instances and has restored function to normal or almost normal in some far advanced and neglected cases of quadriceps insufficiency which, on the initial examination appeared to be hopeless This method is based on the principle that the extent and the rate of development of muscle volume or mass is proportional to the load or the resistance that the muscle must overcome Heavy resistance low repetition exercises are employed to develop hypertrophy and strength in the quadriceps muscle, the method forces the muscle to expend all its potential strength Low resistance and high repetition exercises, such as bicycling, stair-climbing and weight lifting by means of pulleys, develop endurance The latter group of exercises is instituted when the strength of the affected quadriceps approaches that of the normal limb

In attaining maximum hypertrophy the muscle acts against the heaviest load when it approaches complete contraction, not when it is stretched This complies with the principle that the greater the initial stretch of a muscle the greater is its contractile power In the stretched state a muscle calls upon fewer fibers to act against a maximum resistance than would be called upon to overcome the same load in the contracted state Hence, when contracted and acting against maximum resistance, the muscle calls upon a greater number of fibers to overcome the resistance It becomes obvious that by this method a greater number of muscle fibers in a given muscle are stimulated to hypertrophy This is achieved in exercises by attaching the weight directly to the foot

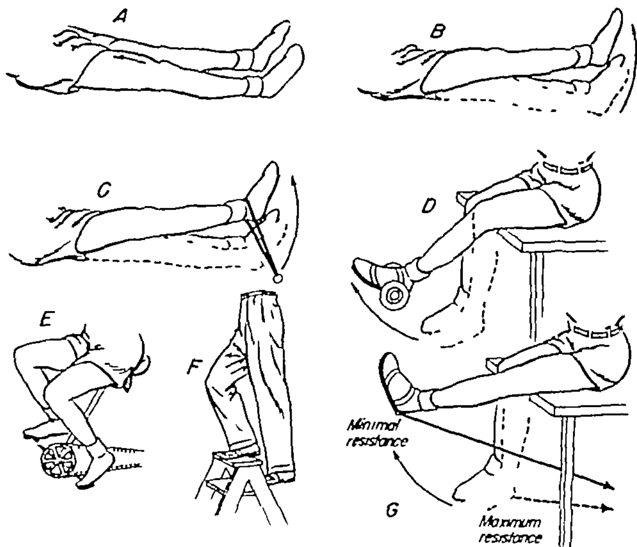


Fig 201 Types of Exercises (A) Quadriceps drill. (B) Straight leg raising (C) Elastic resistant exercise (D) Weight is attached directly to the foot Resistance at *the start of the exercise is minimal it increases steadily as the leg is extended. (F)* Bicycling—an exercise designed for increasing endurance and joint function (F) Stairs-climbing exercise (G) Use of pulley The greater resistance provided by this system is at the start of the exercise the resistance diminishes progressively as complete extension is achieved

On the other hand the pulley system so commonly employed in rehabilitation of the quadriceps enforces the maximum resistance when the muscle is in a stretched state hence it is not adequate in providing heavy resistance exercises so necessary for the development of hypertrophy in this muscle (Fig 201 C) Moreover in the pulley system the vastus medialis works against decreased resistance when the leg is brought into full extension hence it is neglected in the terminal stage of the exercise In order for the vastus medialis to receive the full benefit of the act it should be working against increasing rather than decreasing resistance

METHOD OF HEAVY RESISTANCE AND LOW REPETITION EXERCISES

The program outlined by Delorme is ideal for patients maintained in a center of rehabilitation throughout their entire



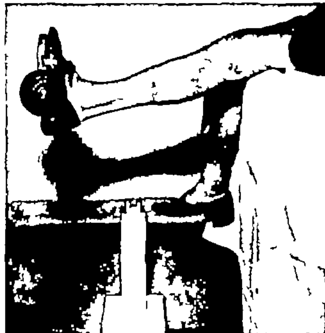


Fig 202 (A, *Left*) Apparatus of Delorme fitted to the foot. The boot alone weighs 5 pounds. Note block used to support the foot. (B, *Right*) After each contraction of the quadriceps and after each series of exercises the foot is brought to rest on the wooden block

od of treatment, such as in a military ›ital However, such a plan is not prac ı in private or hospital practices The ıomic status of most patients will not nit a long period of hospitalization eover, distance in addition to the ıetary standards of most patients, pre les daily supervised physical therapy many weeks It becomes apparent that e other method comprising the above dvantages must be evolved for general

The author employs the armamenta n for quadriceps redevelopment de bed by Delorme however the patients permitted to exercise the affected ex nity at home without supervision for 2 3 days each week The patients are vided with the necessary equipment and given detailed instruction in its use ıerwise the technic is the same as that :ribed by Delorme

APPARATUS

Resistance against the action of the quadriceps is provided by a series of steel plates graded from 1¼ to 5 pounds These are fitted over an iron pipe which is at tached to a steel boot weighing 5 pounds (Fig 202) The patient sits on a wide table 3 feet high the edges of the table are raised 3 inches. A pad approximately 4 inches high is placed under the flexed knees A wooden block is used to rest the limb after each contraction and after each series of exer cises

PROGRAM OF EXERCISES

On the initial examination two deter minations are made (1) the maximum quadriceps power, i e, the maximum poundage that the muscle is capable of raising to the level of full extension of the leg for one repetition (this is designated *one repetition maximum—(1 R.M)*, and (2) the amount of weight which calls for maximum exertion performed 10 repeti tions or 10 repetition maximum (10 R.M)

The determinations are made in the following manner The patient sits on the table and with the pad under the flexed knee the boot then is strapped to the foot. Beginning with the weight of the boot and gradually increasing the load on the foot by adding 1¼ to 5 pounds the patient raises each load to a point of full extension 10 repetitions The load requiring maximum exertion is determined and recorded as the 10 R.M The increase in weights is continued however, with each increase in excess of 10 R M the number of repetitions is decreased Finally the load which can be raised with maximum power for only one repetition is reached this is recorded as 1 R.M

During the first week the patient never exceeds the load of 10 repetition maximum He performs from 7 to 10 series of 10 repetitions daily making from 70 to 100 repetitions for the over-all exercise period *At the beginning of the period he uses* weights considerably less than the 10 R M In each subsequent series the load is increased so that when 10 R M has been reached from 70 to 100 repetitions will have been executed For example at the initial examination the maximum weight that the quadriceps is capable of raising *to full extension for 10 repetitions* (10 R M) is 15 pounds this is designated the maximum weight to be lifted for the first week The patient begins the exercises by adding 1¼ pounds to the load of the boot and performs 10 repetitions before each subsequent series he adds 1¼ more pounds so that he will have performed 100 repetitions when he reaches 15 pounds

At the end of the first week it is expected that some improvement in power of the quadriceps has been achieved hence the new 10 R M is determined and will constitute the maximum resistance which the quadriceps will be forced to overcome during the exercise periods of the following week Also at the end of every 7 or 8 days the quadriceps is called upon to raise the leg to complete extension against the maximum resistance for one repetition (1 R.M) It is interesting to note the progressive increase in maximum power of the quadriceps from week to week provided that the exercises are performed meticulously

Some cases exhibiting severe impairment of the quadriceps muscle such as is often seen in cases immobilized for long periods of time following fracture of the femur or as the result of pronounced scarring and fibrosis following severe violence to the soft tissues of the knee are not capable of lifting the weight of the boot to full extension for 10 repetitions In other words the maximum power of the quadriceps for 10 R M is less than 5 pounds In these cases the boot is not used, but weights of smaller gradations (¼ to 1 pound) are strapped to the foot, the weights are increased after each series of 10 repetitions until the 10 R M is determined

Frequently cases are encountered in which the quadriceps lacks the strength to raise the leg to the point of complete extension In these cases the muscle is severely impaired particularly the vastus medialis Hence the goal of exercise therapy is to concentrate attention on the *vastus medialis in order to restore it to* normalcy only in this way can complete extension be regained in the knee and power of stability attained in the quadriceps as a whole This can be achieved by making the vastus medialis work against resistance through the available range of motion It was pointed out previously that *the vastus medialis comes into forceful* action only in the last 15 of extension however it works in unison with the other components of the quadriceps when acting against resistance In this way sufficient power can be built up in the vastus medialis to effect complete extension The method employed is as follows The maximum load *that the quadriceps* is capable of raising for 10 repetitions to the same level of exten

sion as in acting against no resistance is determined The resistance is increased gradually and this results in a decrease in the range of motion the resistance is in creased until the quadriceps is capable of working through only a very small arc. By exercising the quadriceps in this fashion hypertrophy and power are built up rapidly to the level at which complete extension is possible

EXECUTION OF EXERCISES

The patient sits on the table with a pad under the knee, which is flexed 90° the boot with the weights totaling 10 R.M is strapped to the foot (Fig 202) A block of wood is placed under the boot at the starting position The purpose of this is obvious it precludes any undue stretching and strains on the ligaments and the capsule of the joint resulting from the down ward pull of the applied load in the foot. The leg is raised to the level of maximum extension and then lowered slowly to the starting position so that the foot rests on the block At this point the limb should be relaxed completely for several seconds before the next repetition is commenced The movements should be performed with pre cision, smoothness and rhythm. At the end of each series the limb is rested on the wooden block for 1 to 2 minutes before the next series is started When the limb is raised to the position of maximum exten sion, the patient should make a concerted effort to contract the quadriceps to the maximum degree this tends to call into play an increased number of muscle fibers and is most beneficial to the vastus medi alis

The exercise period usually lasts between 30 and 45 minutes it is performed daily The patients are given the apparatus and instructed to perform the exercises alone at home 2 or 3 days in the week the other days they are supervised in the department of physical therapy As pointed out by Delorme a 2-day rest after each exertion of the maximum power for one repetition is advantageous Also, gentle heat and massage to the limb after each daily exer cise period afford some comfort and en couragement to the patient Weight bearing exercises are not allowed until the power of the affected quadriceps approaches that of the normal muscle.

Following the more common surgical procedures in which the continuity of the extensor mechanism is not interrupted, such as meniscectomy, chondrectomy removal of loose bodies and synovectomy, heavy resistance exercises are not started for 3 or 4 weeks after the operation. At this time effusion and pain on weight bear ing should be minimal Several days before and from 24 to 48 hours after surgical intervention until the time heavy resistance exercises are instituted, quadriceps setting exercises must be performed on a regulated schedule and with concerted concentration on the part of the patient These constitute a very significant part of the training program designed to restore quadriceps power They tend to minimize the intensity of quadriceps atrophy and preserve muscle co-ordination. Restoration of normal power is attained usually in 3 to 6 weeks as a rule cases of meniscectomies respond more rapidly the average time being approximately 3 weeks In cases with impairment of the ligamentous apparatus such as a disrupted anterior cruciate ligament and impairment of the tibial collateral ligaments or other combinations of injuries of the cruciate and the collateral ligaments in which instability of the knee is severe, redevelopment of the quadriceps on the affected side must sur pass normal power in order that the muscle may be sufficiently strong to stabilize the joint in the face of an inadequate liga mentous apparatus

QUADRICEPS SETTING EXERCISES

This is the simplest form, yet one of the most important of all quadriceps exercises When initiated before and immediately

after surgery on the knee joint It prevents mental disorientation of the muscle preserves muscle co-ordination and keeps loss *of muscle volume to a minimum. The* patient must be made aware of the importance of this simple exercise and urged to perform it diligently and with enthusiasm yet it permits the patient to establish voluntary control of the limb Occasionally it may be necessary to assist the patient in performing the act Later it is performed against resistance by placing light sandbags on the dorsum of the foot or by strapping weight on the ankle or against elastic re-

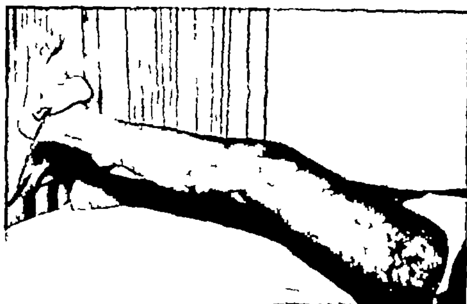


FIG 203 Straight leg raising against elastic resistance

sistance (Fig. 203) When the patient is *ambulatory the exercise may be executed* from a sitting position the loaded leg is *extended as completely as possible* The patient should strive to raise the completely extended limb to the horizontal position Both quadriceps setting and straight leg raising can be and should be *instituted while the limb is in plaster* provided that there are no contraindications to the exercises

He should watch the muscle contract and *at the end of each contraction should en*deavor to expend still more effort It should *be performed 10 15 or 20 times every hour* on the hour depending on the capacity of the patient When quadriceps setting has been mastered sufficiently the patient may add the next exercise straight leg raising

STRAIGHT LEG RAISING EXERCISE

This too is a simple quadriceps exercise

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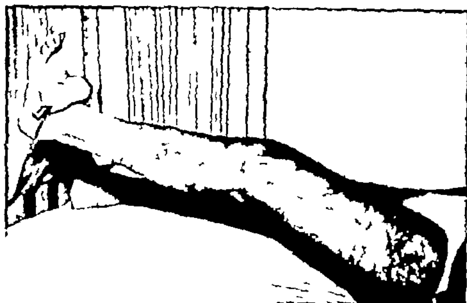


Fig 203 Straight leg raising against elastic resistance

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STRAIGHT LEG RAISING EXERCISE

This too is a simple quadriceps exercise

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7

Congenital and Acquired Deformities of the Knee Joint

CONGENITAL ANOMALIES

Numerous varied and grotesque congenital deformities are encountered in the region of the knee joint. They often exhibit a familial and hereditary distribution Congenital malformations may involve only the elements of the quadriceps apparatus or they may coexist with deformities of the bony components of the knee joint. Frequently, the deformities coexist with other deformities such as clubfeet, clubhands congenital dislocation of the hips and aplasia of some of the bones of the extremities (Fig 204) The knee joint may be absent or dislocated the entire lower limb may fail to develop, or only the thigh may be absent The author had the opportunity to examine a male infant with complete absence of the thigh on the right side the tibia and the fibula were in apposition to the pelvis Also a congenital dislocation of the left hip was present Abnormalities of the extensor apparatus comprise malformations of the patella, underdevelopment or absence of one or more of the vasti muscles, especially the vastus medialis, congenital dislocation and recurrent slipping of the patella, congenital genu recurvatum and other congenital contractures about the knee joint (Fig. 205) In addition, atrophic and hypertrophic congenital abnormalities may be encountered.

It is impossible to record a definitive plan of management for any type of congenital anomaly each case demands individual evaluation, and a plan of treatment is formulated, depending on the requisites of the case in question Atrophic abnormalities of the lower limb rarely are amenable to surgical measures However, in properly selected cases, retarding or arresting the growth of the normal limb may minimize in a measure the degree of the deformity Such procedures also are applicable to hypertrophic anomalies of the lower extremity In these cases growth of the affected extremity is retarded until *equalization of leg length is achieved.*

Case G W, a white female 9 years old, is an example of congenital hypertrophic anomaly implicating the right leg (Fig. 206) The mother noticed immediately after birth a slight enlargement of the limb as compared with the opposite extremity With growth of the child there was a steady increase in the discrepancy of leg lengths When first examined by the author the right leg was 7 cm longer than the left, and the circumference of the right thigh 4 inches proximal to the upper border of the patella was 4 cm. greater than the corresponding level on the opposite thigh Both the lower femoral epiphysis and the upper tibial epiphysis were stapled, the fibular epiphyseal plate was excised. Two years later the lower limbs were of equal length and the staples were removed 3 years later the right extremity was 1½ cm. longer than the left.

Absence of the Femur

Partial or complete absence of the femur occurs more frequently than is realized generally Of all the long bones the fibula is congenitally absent most often in the

order of frequency the other long bones congenitally absent are the tibia, the ulna and the radius. The author has encountered 6 cases of partial or complete absence of the femur the most recent case exhibited the most interesting findings The patient is a Negro child born on October 10, 1952, with a deformed right lower extremity Roentgenographic studies revealed total absence of the femur and the fibula in the right lower limb the left extremity was normal (Fig 207 A) Palpation of the affected thigh disclosed the presence of a round, firm rubbery mass measuring 5 cm by 7 cm Close observation of the mass during the subsequent 3 weeks revealed

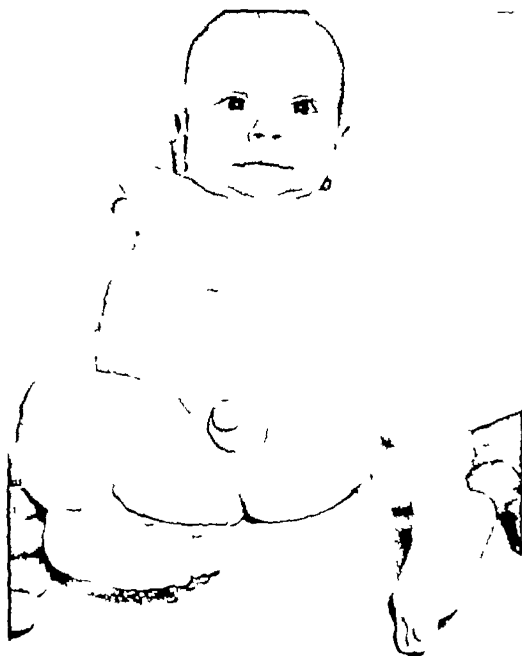


FIG 204 Congenital absence of both tibae with absence of both upper extremities Only the proximal ends of both humeri are present Both knee joints are dislocated the head of the fibula on either side is displaced upward

that it grew in size steadily This prompted a surgical biopsy of the lesion microscopic examination of the tissue disclosed that the mass comprised normal cartilage Roentgenograms taken 4 months later revealed some calcification in the palpable mass (Fig 207 B) however, there was no evidence of the development of a normal femoral shaft or of the femoral epiphyses. Roentgenograms taken when the child was 7 months old exhibited the presence of the upper femoral epiphysis in normal relation to the acetabulum and the presence of the distal half of the femur with a well-developed lower femoral epiphysis (Fig 207 C) The proximal end of the femur distal to the capital epiphysis was still absent It will be interesting to follow the ultimate development of this extremity

Another case of interest was a child 6 years of age with a total absence of the left femur the left lower leg was normal in every feature except that it was markedly underdeveloped The child was fitted with a prosthesis which accommodated the lower leg and the flail thigh It was amazing to observe the ease with which the patient was able to move about.

In general, the treatment of these cases like those of other congenital anomalies depends upon the requirements of the individual problem. Management of these cases tests the ingenuity of the orthopedic surgeon in charge



Fig 205 Child born with extension contractures of both knees and flexion contractures of both hips and shoulders (a form of myodystrophia foetalis)

Absence of the Tibia

Congenital absence of the tibia produces marked shortening of the lower leg, which usually assumes a position of extreme adduction on the thigh Frequently concomitant anomalies of the foot are present such as absence of some of the tarsal bones the toes or the rays Generally the foot exhibits varying degrees of equinovarus deformity Roentgenographic study discloses the usual arrangement of the upper end of the fibula in relation to the femur and the lower end to the posterior tarsus The upper end of the fibula articulates with the lateral aspect of the lateral condyle of the femur and the lower end is in apposition to the lateral aspect of the posterior tarsus (Fig 208) In some instances heredity plays a role in the development of this anomaly The author has encountered bilateral congenital absence of the tibia in a father and his daughter with severe coexisting deformities of the feet bilateral amputations through the knee joints were performed in each

Fig 206 (*Left*) G W aged 9 with congenital hypertrophy of the right lower extremity (*Center*) Both the distal femoral and the upper tibial epiphyses were stapled (*Right*) Same child 2½ years later The right leg is now only 1½ cm longer than the left.



Fig 207 (*Left*) At birth there is absence of the femur and the fibula in the right lower extremity (*Center*) Four months after birth calcification without any special configuration is noted in the thigh. (*Right*) Seven months after birth. Note the presence of a proximal femoral epiphysis and the development of the lower one half of the femur with a well formed distal epiphysis

instance By these procedures the distal femoral epiphyses were not disturbed, and lengthening of the femurs progressed normally (Figs 209 and 210)

TREATMENT

As a rule, conservative measures produce unsatisfactory limbs and in most instances amputation performed at the optimum time is the procedure of choice when the tibia is absent In cases with resistant foot deformities, during the first 2 or 3 years of life such methods as manual stretching and wedging casts may be employed to overcome the deformity and place the foot in position as nearly normal as possible in relation to the longitudinal axis of the lower leg In a few instances in which the coexisting deformities of the foot are amenable to satisfactory correction the fibula may be transferred into the intercondylar notch of the femur and the distal end mortised in the superior aspect of the astragalus or the os calcis if the former is absent By this method the bony continuity of the limb is restored, and weight bearing function can begin this tends to minimize retardation of growth or provides a serviceable stump for a prosthesis if amputation is inevitable in later years By



Fig 208 Bilateral absence of the tibia Observe that the upper ends of both fibulae articulate with the posterolateral aspect of the lateral femoral condyles.

placing the foot in extreme equinus in the longitudinal axis of the limb additional length is added to the extremity Putti has designed surgical procedures to achieve these aforementioned aims and has reported some satisfactory results

Transference of the Fibula (Putti) (Fig 211) An oblique incision is made on the anterolateral aspect of the limb, beginning above the level of the lateral condyle of the femur and extending distally to the conjuncture of the upper and the middle thirds of the leg The incision is deepened to expose the condyles of the femur the *intervening capsule between the lateral* condyle of the femur and the proximal

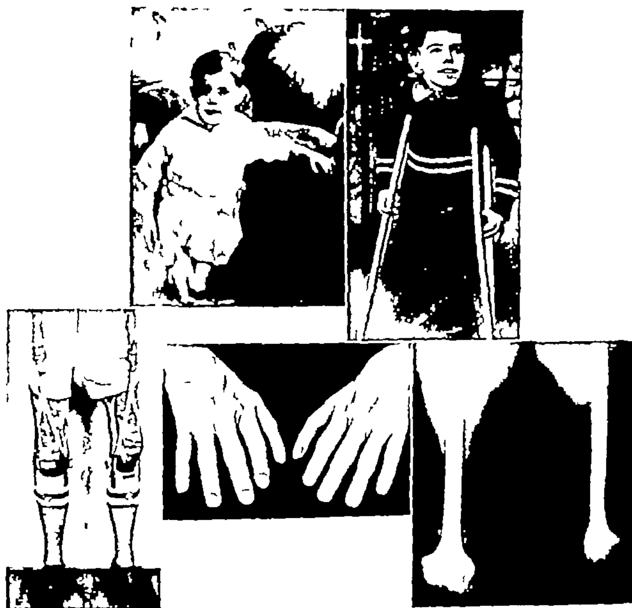


Fig 209 (*Top left*) R F at the age of 3 Both tibiae are absent observe that the child stands on the ends of the femurs (*Top right*) The same child at the age of 6 A *bilateral amputation through the knee joints has been performed* (*Bottom left*) Same patient at the age of 36 wearing prosthesis. He is able to walk without difficulty and is capable of working every day (*Bottom center*) Hands of the same patient (*Bottom right*) Roentgenograms of the same patient. No evidence of degenerative changes caused by weight bearing is demonstrable in the lower end of either femur

Fig 210 (A, *Top*) Roentgenograms of the lower extremities of the daughter of the patient shown in Figure 209 Observe the bilateral absence of the tibia with dislocation of the knee joints also note the congenital abnormalities of both feet. (B, *Bottom*) Hands of this child Note that they are identical with the hands of the father



epiphysis of the fibula is divided Next, the common peroneal nerve is identified and retracted laterally and the tendon of the biceps femoris is severed at its point of attachment to the fibular head The upper third of the fibula is mobilized In the execution of this step care must be taken not to injure the peroneal nerve Now the fibula is ready to be transferred to its new anatomic position in the intercondylar notch of the femur This is accomplished by levering the end of the bone gently into the notch this step may be facilitated by abduction and flexion of the leg The shortened soft tissue structures of the thigh may not permit complete extension of the leg on the thigh in this event the leg is maintained in slight flexion Complete extension may be achieved later by successive casts

If the stability of the fibula in the notch is satisfactory no fixation of the bone in the notch is attempted on the other hand, if stability is not satisfactory, the surface of the notch may be scarified and the fibula anchored in place with interrupted sutures The wound is closed in the usual manner

POSTOPERATIVE MANAGEMENT At the termination of the operation a plaster cast is applied extending from the groin to the toes with the knee flexed in the desired position Every 4 to 6 weeks the cast is removed and another is applied with each change of cast extension at the knee is increased until 180° is attained Correction at the knee usually is accomplished at the end of 6 months, a leather lacer is fitted extending from the groin to the toes and holding the foot in equinus. Walking on the limb is encouraged.

Stabilization of Distal End of the Fibula. Stabilization of the lower end of the fibula is performed approximately 1 year after the first operation The distal end of the fibula is placed into the tarsus This is achieved by mobilizing the end of the fibula through an anterolateral incision The superior surface of the astragalus is exposed and split longitudinally If this bone is absent the mortice is made in the os calcis *If an increase in the length of the leg is desired the foot is placed in equinus* with the toes at right angles to the metatarsal bones so that the body weight is borne on the metatarsal heads and the toes The distal end of the fibula is scarified and levered into the defect the end of the bone is anchored in position by several interrupted sutures

With the foot in equinus and the knee in complete extension the extremity is immobilized in a plaster cast extending from the groin to the toes After 3 or 4 months the cast is removed a leather lacer is fitted to the leg and an elevated shoe is worn on the foot

Modifications of the aforementioned pro



FIG 210 (C *Left*) The child wearing prosthesis at the age of 8 Amputations done at the age of 4 (D *Right*) Roentgenograms showing the adaptation of both femoral epiphyses to weight bearing (A Davidson)

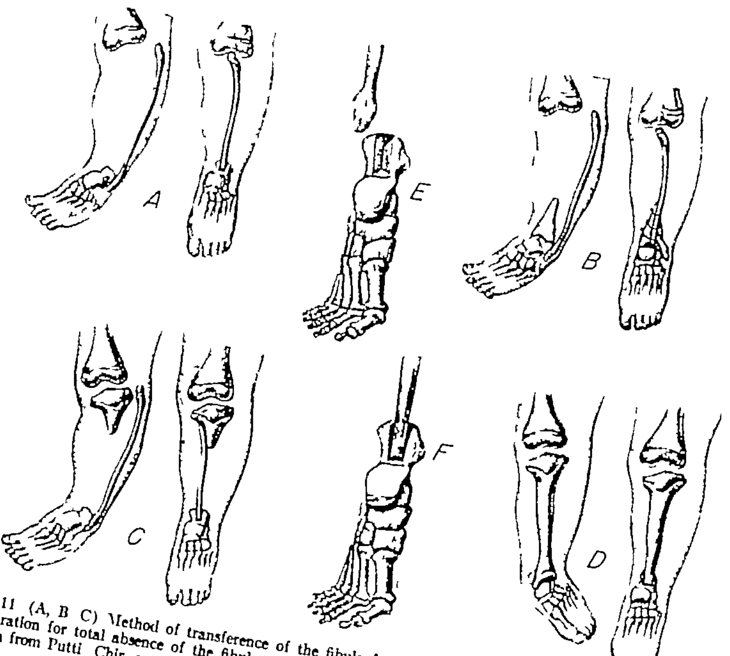


Fig 211 (A, B C) Method of transference of the fibula ...
(D) Operation for total absence of the fib...
(Redrawn from Putti Chir ...



Fig 212 Child with absence of the fibula in the left leg Observe the characteristic position of the foot It assumes a position of talipes equinovalgus. Also note the concomitant deformities of both feet



Fig 213 Characteristic anterior bowing of the tibia in the absence of a fibula

cedure may be employed in cases with partial absence at either end of the tibia. If the proximal end of the tibia is present, the fibula may be fused to its lateral aspect and the distal end of the fibula transferred into the posterior tarsus If the proximal end is absent, the upper end of the fibula is placed into the intercondylar notch (Fig 211)

Amputation Through the Knee Joint. Although amputations in growing children are looked upon with disfavor in some instances they are justified provided that the amputation is performed through the knee joint and the distal femoral epiphysis is not disturbed An appliance can be worn to permit walking function will be a major stimulus in promoting growth of the femur The author has observed two cases father and daughter who had bilateral amputations in childhood In both instances excellent weight bearing stumps were attained and both patients wear prostheses without difficulty

Absence of the Fibula

This anomaly occurs more frequently than congenital absence of the other long bones of the extremities Complete or partial absence of the bone may occur The foot characteristically assumes a position of talipes equinovalgus and concomitant abnormalities of the foot usually are present (Fig 212) In addition the tibia exhibits varying degrees of anterior bowing (Fig 213) Bilateral defects of the fibula also are encountered

Coventry and Johnson have divided the different varieties of fibular defects into three groups Type I includes patients with partial unilateral absence of the fibula with minimal or no anterior angulation of the tibia In this group the affected limb is always shorter than the opposite extremity and the foot exhibits little or no abnormality The functional handicap is not great



FIG 214 (A, *Left*) Child aged 4, with complete absence of the right fibula Note the amount of shortening in the entire affected limb and the equinus position of the foot which is a secondary deformity to gain in leg length (B *Right*) Roentgenograms of the same child, showing complete absence of the fibula.

in fact in some instances the lesion is not recognized and is found only accidentally Treatment usually comprises an elevation of the heel on the shoe worn on the affected limb, and in cases with marked shortening epiphyseal arrest may be employed to equalize leg lengths.

Type II includes cases with complete or almost complete absence of the fibula the involvement is unilateral This is the second largest group of cases. As in the first type the characteristic deformity is demonstrable The tibia presents marked anterior angulation the foot is in a position of talipes equinovalgus and usually discloses other deformities such as absence of rays or tarsal bones, and invariably marked shortening of the limb is present (Fig 214)

Type III is the largest group it includes all cases of Types I and II with other associated deformities and all cases of bilateral absences of the fibula. Treatment of this group is more complicated than that of Types I and II, also, the prognosis for ultimate satisfactory function is poorer

Occasionally congenital absence of the tibia may be diagnosed erroneously as congenital absence of the fibula. The distinguishing features of congenital absence of the tibia are as follows (1) the foot is in a position of varus, while in congenital absence of the fibula it is in a valgus position,



Fig 212 Child with absence of the fibula in the left leg Observe the characteristic position of the foot it assumes a position of talipes equinovalgus. Also note the concomitant deformities of both feet.



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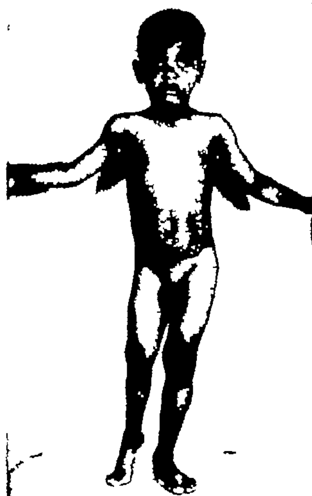




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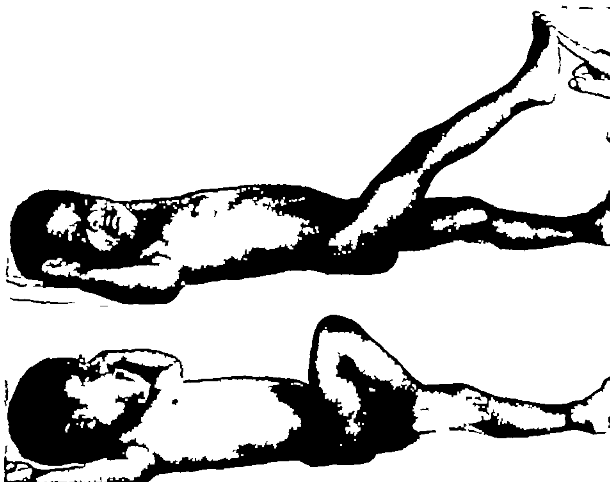


Fig 214 (C) Showing range of flexion and extension in the affected knee joint Lateral stability of the knee is surprisingly good

the medial malleolus is not present and the foot is displaced medially at the ankle joint (2) the leg fails to exhibit marked anterior angulation (3) the knee is dislocated and the fibula articulates with the lateral aspect of the lateral femoral condyle

TREATMENT

As previously noted no generalized plan of management is applicable to all the different types of anomalies of the lower leg In cases of absence of the fibula each instance presents problems peculiar to the abnormality Types II and III require special consideration. Treatment should begin as soon after birth as circumstances permit In general every effort should be made to encourage weight bearing in order to stimulate bone growth. In the early years t deformity of the foot should be correc by wedging or successive casts and by placing the foot in a position of satisfactory weight bearing The use of appliances or specially designed shoes or prostheses is employed to maintain the corrected position permitting weight-bearing. Operative procedures such as tendon lengthening capsulotomy and tenotomy may be necessary to attain the desired correction of the foot in relation to the lower leg

When skeletal growth is almost completed the foot may be stabilized by the reconstruction of an external malleolus as described by Ashhurst. A free bone graft ¼ in in width and 4 in in length is obtained from the opposite tibia. One end of the graft is shaped to conform to the shape

of a normal internal malleolus, the en dosteum is removed and the cortical sur face is opposed to the lateral surface of the distal end of the tibia so that the end of the graft extends 1 in beyond the distal margin of the tibia The graft is fixed to the tibia by several screws.

The limb is immobilized in a plaster cast extending from the toes to the groin, weight bearing in a walking cast is allowed at the end of 8 weeks. Twelve weeks after operation the cast is removed, and the leg is protected by a leather lacer for 6 to 8 months

Epiphyseal arrest may be employed to equalize leg length, and tarsal arthrodeses to correct the valgus deformity of the foot. Epiphyseal arrest should not be done un less there is some assurance that most of the inequality of length can be corrected If a patient must wear a prosthesis because of shortening existing even after epiphyseal arthrodesis, then the loss of height produced by the procedure is not justified Severe bowing of the tibia may require osteotomy to gain some length and also to overcome some of the equinus deformity of the foot Coventry and Johnson point out that when osteotomy is considered, length ening or division of the posterior and lateral structures of the leg is necessary in order to achieve the correction Healing at the osteotomy site usually occurs without delay or complication.

Amputation in some instances is the procedure of choice from the viewpoints of better function and cosmetic appearance As noted previously when possible the procedure should be delayed until skeletal maturation is attained However, in some cases it may be justified even in growing children provided that function and weight bearing can be improved in order to avoid extreme loss of growth which is the usual sequel of nonweight bearing. In chil dren the amputation of choice is one per formed through the knee joint without disturbing the distal epiphysis of the femur



Fig. 215 Congenital genu recurvatum. Observe the transverse skin creases in the anterior aspect of the knee, the con dyles of the femur project into the popliteal space

Congenital Genu Recurvatum

This anomaly is characterized by ex treme hyperextension of the tibia on the femur, in severe cases a true dislocation of the knee exists, with the tibia lying in front of the femur (Fig 215) The causative agent responsible for the deformity is not known however, Middleton has advanced a very plausible theory He is of the opin ion that degeneration of the quadriceps muscle occurs in utero (myodystrophia foetalis), this is followed by contracture

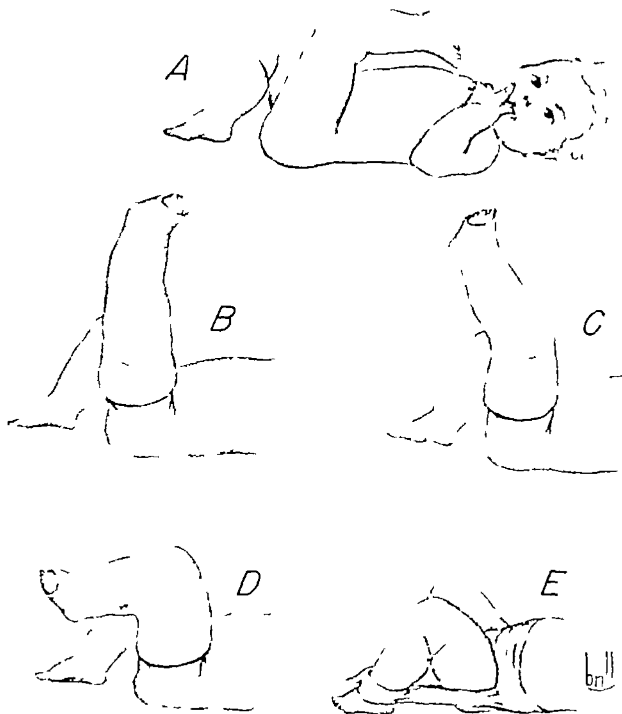


FIG 216 Correction of genu recurvatum by successive casts and method of maintaining the correction.

of the muscle mass on the anterior aspect of the leg which during intra-uterine growth pulls the knee into a position of recurvation

Physical examination reveals that the knee is fixed in hyperextension attempts made to flex the joint are opposed by an elastic resistance offered by the extensor apparatus. Several transverse skin creases are discernible on the anterior aspect of the knee joint and the patella may be under developed or absent Palpation of the poste

rior surface of the joint discloses prominent femoral condyles projecting into the popliteal space and taut hamstring muscles. Frequently, the anomaly coexists with other contractures or skeletal deformities, such as congenital dislocation of the hips clubfoot and clubhand

MANAGEMENT

The aim of the treatment is to effect sufficient stretching of the quadriceps muscle to permit anatomic repositioning of the articular surface of the tibia in relation to that of the femur Treatment should begin immediately after birth In mild cases stretching of the quadriceps may be achieved by successive casts, with the application of each cast the degree of flexion in the knee joint is increased gradually In the beginning the process should be executed gently and slowly in order to avoid injury to the epiphyses. After maximum flexion is attained, recurrence of the deformity is prevented by a strap extending from an anklet to a pelvic band (Fig 216) This method should be tried in children under 2 years of age

In severe deformities which fail to respond to manipulative measures or in cases which show a marked tendency to relapse surgical intervention is indicated to overcome the contracture The quadriceps tendon is lengthened by a Z-shaped incision and the knee is forced into the maximum amount of flexion attainable without inflicting damage to the epiphyses

Correction is maintained by a plaster cast holding the knee at 90° flexion After 8 to 10 weeks the cast is removed, and physical measures are instituted to restore active flexion and extension. There is a strong tendency toward recurrence of the deformity This is prevented by fitting the child with a brace which locks just short of complete extension The appliance not only prevents recurrence of the recurvatum deformity but also protects the limb from developing a knock knee deformity The brace should be employed until there is clinical evidence that a relapse will not occur, this may mean wearing the appliance for several years Further protection is provided by wearing night splints to maintain the corrected position At best, the ultimate functional result attained is far from that of the normal limb

STIFF KNEE SUBSEQUENT TO INJURIES OF OR ABOUT THE KNEE JOINT

General Considerations

Major injuries inflicted on the knee joint or at a distance to the joint are frequently responsible for varying degrees of stiffness in the articulation In many instances, particularly in fractures of the femur, the ensuing disability is a serious handicap to the patient. In order to prevent stiffness and to treat adequately existing flexion deformities comprehension of the functional mechanics of the knee joint is essential. Rhythmic normal flexion and extension is possible because of the following prime factors

1 During flexion the massive quadriceps apparatus is capable of considerable lengthening, sufficient to allow full flexion of the joint Also during extension this apparatus exhibits marked powers of contractibility sufficient to achieve full extension of the lower leg even against great resistance Any interference with this mechanism may restrict the full excursion of the quadriceps, producing varying degrees of limited motion at the knee joint It becomes apparent that adhesions binding the quadriceps to the shaft of the femur severely impede normal function of this muscle mass Also intramuscular fibrosis not only binds the muscle to the surrounding tissues but also actually reduces its elasticity, thereby becoming an important factor in causing stiffness of the knee joint.

2 Normal function of the quadriceps depends upon the integrity of gliding mech-



FIG 217 (*Left*) Multiple surgical scars of the thigh. *The two uppermost incisions* are responsible for fixation of the quadriceps in this instance (*Right*) The patient had only 20° of motion in the joint (from 170° to 150°) The lower scar is properly placed (*between the vastus lateralis and the biceps femoris muscles*)

anisms in and about the knee joint The quadriceps is enveloped in a dense fibrous sheath (fasciae of the thigh) which permits the muscle to glide freely within it. Adhesions between this structure and the quadriceps restrict the free movements of the latter This is observed frequently in cases subjected to surgery with malplaced incisional scars Scars on the anterior or the anterolateral aspect of the thigh are particularly prone to restrict the normal movability *of the quadriceps (Fig 217)* When possible incisions should be made in line with natural muscle planes such as between the vastus interalis and the biceps femoris muscles As previously recorded *the tibial collateral ligament moves forward* on the femoral and the tibial condyles during extension and backward during flexion Obliteration partial or complete of this mechanism is reflected in restricted motion at *the knee joint*

3 The knee joint is endowed with the largest synovial cavity in the body This is necessary in order to permit it a great arc of motion Essentially it provides a gliding mechanism for the quadriceps apparatus especially the patella The suprapatellar pouch is the most important portion of this synovial cavity Adhesion formations in the cavity particularly in the suprapatellar pouch and in the medial and the lateral compartments impede the free excursion of the extensor apparatus and hence restrict movements of the joint.

4 The marked laxity of the skin and the subcutaneous tissue about the knee enhances free movements of the joint. Ex*tensive scar formation implicating these* structures such as results from burns and infected wounds tends to limit the movements of the joint.

In the light of the aforementioned ob*servations it becomes obvious that in the* management of major traumas to or about the knee joint a concerted effort must be made to preserve the integrity of the quadriceps mechanisms and its gliding mech*anisms This is achieved best by measures* which will maintain or restore rapidly normal quadriceps power and volume and prevent the formation of adhesions in the gliding mechanisms In order to achieve *this goal one must be familiar with certain*

clinical truths. Prolonged immobilization is not the prime factor responsible for stiffness in the knee joint This is attested by the observation that as a rule fractures of the tibia in which union is delayed for 6 months or more do not result in persistent restriction of flexion. Also, in severe ligamentous injuries of the knee joint without osseous involvement which have been immobilized for 10 weeks or more, restoration of good function is the rule. Sir Robert Jones observed the surprisingly good results attained following major injuries to the ligaments in complete dislocation of the knee joint when treated by plaster immobilization. However, in fractures of the femur lesser periods of immobilization invariably result in pronounced stiffness return of flexion is slow and permanent dysfunction ensues in a large number of the cases It becomes apparent that immobilization per se and injuries of the intra-articular and the extra-articular structures without fractures of the femur play only a minor role in producing stiffness and that these obstacles can be overcome readily On the other hand, fractures of the femur are associated with factors which may resist all known mechanical methods to attain good motion at the knee joint Essentially this factor is the formation of adhesions within the deep layers of the quadriceps especially the vastus intermedius which bind the extensor apparatus to the shaft of the femur Charnley points out that the extent of the fibrosis in the quadriceps and adhesion to the underlying bone is predicated upon the rapidity of union at the site of fracture If bony union occurs quickly, an excellent range of motion may be anticipated this is also true in cases treated with the knee immobilized completely This worker noted some significant observations in a series of 34 fractures of the femur in which movement was not begun until clinical evidence of bony union was discernible The cases with demonstrable union at or before 8 weeks exhibited an average range of motion of 114 1° 6 months after the fracture Those showing clinical bony union after 8 weeks (average time was 15.3 weeks) disclosed an average range of motion of 74.5° 6 months after fracture. One year after fracture the average range in the first group was 129 1° and in the second 113 5° It is interesting to note in this study that early motion does not ensure restoration of full knee motion full flexion depends on complete absorption of fibrous tissue situated in the vicinity of the fracture site. With absorption of the binding adhesions, the quadriceps is free to permit full flexion.

The above study allows one to conclude that the "ultimate range of motion depends upon two factors a mechanical factor related to mobilization by physical processes and a biologic factor relating to the amount of scar tissue produced in the quadriceps" During the reparative process the biologic factor governs the fate and the disposition of the tissues of repair In some cases bony union progresses rapidly, and bony callus is discernible early (3 or 4 weeks) by roentgenographic study In these cases, solid, bony union occurs early, and good knee motion is achieved readily It appears that abundance of bony callus is associated with minimal fixation of the quadriceps to the underlying bone. On the other hand, failure to develop bony callus within the first 6 weeks after fracture indicates that nature is attempting to effect union of the fragments by mature fibrous tissue which implicates the deep components of the quadriceps binding them to the shaft of the femur The explanation for this frustrated attempt at repair is not undersood, but it is reasonable to conclude that it is the same mechanism acting in delayed union. When bony union is ultimately attained in these cases, the larger proportion of them exhibit severe impairment of motion, regardless of whether mechanical measures were employed early in the treatment to mobilize the knee joint.

However, one must not conclude from the above observations that early motion and active exercises are prejudicial to good function Active muscle contractions are necessary to maintain metabolism of the tissues of the affected limb at an optimum level also, severe quadriceps atrophy is prevented and the neuromuscular mechanism is not lost There is sufficient clinical evidence to show that preservation of tone and volume of the musculature of the leg enhances rapid return of knee flexion. Also, active motion at the knee joint during treatment of fracture of the femur keeps the formation of intra articular adhesions at a minimum and ensures mobility of the patella, a feature essential to attain rapidly full flexion

SAFEGUARDS AGAINST LOSS OF FLEXION

The goal in the treatment of fractures of the femur, like fractures elsewhere in the body, is to attain bony union and to restore full function of the limb and of the body as a whole in the shortest period of time possible In the case of fractures of the femur after union is attained return to normalcy of the lower limb is governed by the extent of motion in the knee joint. A restricted painful arc of motion particularly if full extension is lacking is a serious disability In turn, knee motion is governed in a large measure by the rapidity of bony union as noted previously, early bony callus is associated with attainment of rapid and satisfactory range of motion whereas delayed union invariably is followed by marked restriction of motion It becomes apparent that a concerted effort should be made to promote the formation of early callus In a large measure this is influenced by the choice of treatment made



FIG 218 (*Left*) Fracture of the shaft of the femur at its middle treated by intramedullary nailing The patient was 32 years old. (*Right*) Observe the range of active extension and flexion 3 weeks postoperatively

by the surgeon and the avoidance of many pitfalls which tend to favor delayed union

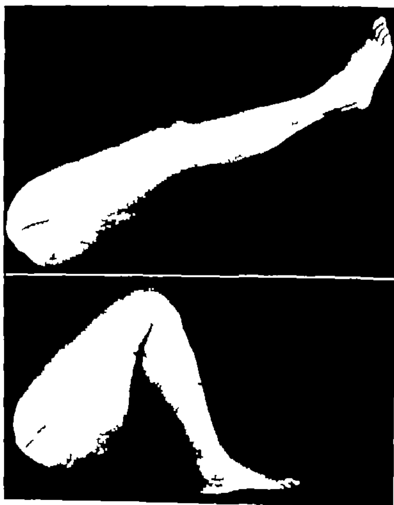
Correct Choice of Methods to Treat Fractures of the Femur

Every fracture of the femur presents different problems it is of prime importance that the method of treatment chosen meet the requirements of the individual case In the younger age groups, particularly adolescents and young adults, the powers of osteogenesis are extremely active, and the joints of the affected limb are free of degenerative changes however in patients past middle life and in the elderly, delayed union is not uncommon, and degenerative alterations in the joints are observed frequently The management of supracondylar and condylar fractures of the femur is described in Chapter 9, Fractures and Wounds About the Knee Joint"

Fractures of the middle third of the femur occurring in the young adult are best treated with skeletal traction with the limb balanced in a Thomas splint with a Pearson attachment. The author prefers skeletal traction made by a threaded wire passing beneath the tibial tubercle The efficacy of this method should be determined within the first 10 days If it becomes obvious that satisfactory alignment and apposition of the fragments is not possible hence precluding the formation of early bony callus then immediate surgical intervention must be considered Failure to recognize early the inadequacy of one method must be condemned If several months are allowed to elapse before deciding that another method of treatment is more desirable, much valuable time is lost delayed heal

Fig 219 (*Left*) Upper shaft fracture in a female, aged 69, treated by intramedullary nailing Observe the callus formation at the end of 6 weeks and the degenerative changes in the hip Similar changes are present in the knee joint. (*Right*) Range of active extension and flexion 6 weeks postoperatively





ing and prolonged immobilization ensures varying degrees of permanent restriction of flexion. The above principle is applicable to all types of fractures of the femur Plating of a femoral fracture in this region is no longer employed by the author this method not only inflicts considerable surgical trauma to the fracture site but in addition does not eliminate prolonged immobilization. In these cases, if no contraindications exist, insertion of a Kuntschner nail is more desirable. This method ensures adequate fixation and alignment of the fragments, permits early ambulation of the patient favors early formation of bony callus and enhances rapid return of knee motion In properly selected cases and in operations performed by competent surgeons, the value of intramedullary nailing cannot be questioned In the older age groups it is the method of choice provided that there are no complicating factors (Fig 218) It is amazing how little dysfunction ensues when this method is used, even in patients with moderate degenerative changes in the knee joint. The reason is apparent the method permits continuance of normal joint function a factor essential in preventing stiffness and loss of flexion Clinical experience teaches that immobilization of the knee joint afflicted with degenerative arthritis invariably is followed by restricted motion which in many instances may be permanent.

Fractures of the upper third are notorious for the difficulty they present in attaining and maintaining satisfactory reduction by the orthodox closed methods. In all adults the preferred method is intramedullary nailing In this category of cases plates are not applied for the same reasons recorded in the discussion of fractures of the middle third of the femur (Fig 219)

The treatment of fractures of the femoral neck and the trochanteric region by internal fixation permits early ambulation of the patient and allows normal motion at the knee joint These features outweigh those offered in favor of treatment by continuous traction or immobilization in a plaster spica Continuance of normal joint motion at the knee is of special significance in these cases because the patients are advanced in years and degenerative abnormalities of varying severity in all joints especially the knees and the hips, are invariably present Moreover, this age group tolerates poorly prolonged immobilization whether it be by plaster or continuous traction.

Early Mobilization of the Limb

Regardless of the method of treatment adopted, active contraction of the muscles of the thigh and the calf should be instituted early and continued on a regulated regimen throughout the entire course of treatment. By so doing extensive muscle atrophy and loss of power in the aforementioned muscles, especially the quadriceps is prevented also the gliding mechanism of the patella is preserved If the treatment chosen makes the patella accessible the patella should be moved passively in all directions by the patient for 3 to 5 minutes on the hour throughout the day

Certain methods of treatment lend themselves to early knee flexion exercises this is especially true of intramedullary nailing and the application of a plate Also after reduction and stabilization of the fragments the Thomas splint with a Pearson attachment allows early mobilization of the knee joint. Flexion exercises always should be started from the extended position and executed conscientiously under direction and supervision until the patient can be trusted to assume the responsibility of the program At all times the exercises should be performed within the tolerance of the patient and forceful passive maneuvers should be avoided these tend to precipitate local tissue reactions in and around the knee joint which defeat the aims of the treatment Passive stretching under anesthesia during the early stage of healing in

variably produces soft tissue damage which is followed by diminution of the arc of motion present prior to manipulation and retards rehabilitation of the patient.

Surgical Procedures

In the event that open reduction and fixation of fractures of the femur are deemed the method of choice, and in cases requiring bone grafting to attain bony healing the surgical procedures should be so conceived that minimal damage is inflicted to the quadriceps apparatus and its gliding mechanisms It is not uncommon to encounter cases in which the surgeon has violated the very basic principles of surgery in an effort to expose the fracture site or the seat of pathology in the femur Operations should be so designed that the bone is exposed by separating muscle planes rather than by cutting through muscle bellies The latter method causes the formation of scar tissue in the muscles fixing these structures to one another and to underlying bone No surgeon who has the slightest regard for the integrity of the quadriceps will employ an anterior incision to expose the femur The unfortunate victim of this procedure struggles many months to attain a few degrees of flexion motion in the knee joint, and in most instances the ultimate result is far from acceptable. In such cases if union is delayed demanding prolonged immobilization the resulting dysfunction is permanent and severe (Fig 217) The posterolateral incision provides adequate exposure of the femur without cutting through muscle masses The bone is exposed in the interval between the biceps femoris and the vastus lateralis

Care should be executed to prevent hemorrhage in the muscles This is best achieved by subperiosteal stripping on the other hand the extent of periosteal stripping should not be extensive for it impairs the blood supply of the bone ends and favors delayed union Rough handling and strong and prolonged traction of muscles is indefensible, such disregard for tissue favors extensive formation of scar tissue

When possible, the suprapatellar pouch should be preserved and spared unnecessary surgical trauma Laceration of and hemorrhage into this synovial pouch enhances the formation of intracapsular and extracapsular adhesions which limit the normal excursion of the patella on the anterior surface of the femur The same precautions noted above should be taken when the femur is exposed for the purpose of eradicating some pathologic process such as a bone cyst or an osteomyelitic area

If open methods are adopted for treatment of fracture of the femur the means of internal fixation should provide immediately sufficient stability to permit early mobilization of the knee Intramedullary fixation meets this requirement and should be the method of choice Also, this method may be employed in combination with bone grafting of the fracture site. As a rule when a decision is made to implant a bone graft across the fracture site, marked loss of flexion at the knee joint is present, resulting from prolonged immobilization of the limb and fixation of the quadriceps to the shaft of the femur In such cases the ideal method of treatment is intramedullary nailing with application of numerous strips of cancellous bone across the fracture site encircling the entire circumference of the shaft. This method precludes further immobilization and facilitates institution of exercises designed to restore joint function The numerous excellent results recorded in the literature obtained by this method or a modification of it attests its efficiency

Management

Stiffness and restriction of flexion subsequent to minor injuries of the knee joint and following surgical procedures, such as removal of loose bodies, meniscectomy and repair of the collateral ligaments, are usu

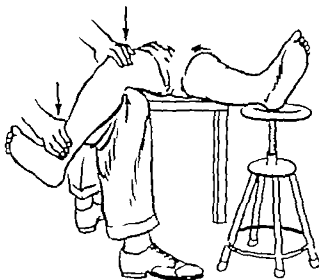


FIG 220 Method employed to manipulate the knee joint.

ally *amenable to simple measures designed* to maintain good muscle power, tone and neuromuscular co-ordination. The regimen employed to achieve full restoration of knee function in these cases is recorded in Chapter 6 "Disorders of the Extensor Apparatus of the Knee Joint.

MANIPULATION

Manipulative therapy is recognized as a valuable method to improve joint motion provided that it is performed in properly selected cases Failure to evaluate adequately the cases subjected to this form of treatment is responsible for the many poor results attained and *in some instances for* further loss of motion The procedure is *particularly indicated in cases of traumatic* lesions with mild or moderate fibrosis of the capsular and the extra articular tissues with minimal formation of scar tissue in the deep components of the quadriceps and with little or no implication of the intra articular tissues It is of doubtful value in cases with severe scarring of the quadriceps muscle especially the vastus intermedius component which is bound to the shaft of the femur by tough, inelastic adhesions or in cases with the extensive fibrosis in the suprapatellar pouch and in the tissues lateral to the patella In the latter inst[a]nce the patella is *fixed firmly to the femu[r]* [by] the surrounding adhesions and is capabl[e of] very little upward or lateral mobility [As] previously recorded, manipulation n[ever] should be considered *during the active* [re]parative phase following injury If [em]ployed at this time violent tissue reac[tion] invariably ensues which intensifies fi[bro]blastic proliferation and deters recovery [If] roentgenographic studies disclose exten[sive] osteoporosis of the bony elements mani[pu]lative maneuvers are contraindicated. [In] such instances the strength of the adhesi[ons] may be greater than the resistance off[ered] by osteoporotic bones Fracture of the [pa]*tella or crushing of the articular surf[aces]* may occur fractures may also occur w[hen] *the procedure is executed with extreme c[are]*

Occasionally synovectomy perfor[med] *for villonodular synovitis osteochondro*[ma]tosis or chronic synovitis of the knee j[oint] is followed by loss of flexion in spite [of] adequate measures instituted early to [re]store joint motion If no increase is no[ted] in the arc of flexion after a 6-week per[iod] of intensive exercises and physical thera[py] *manipulative therapy is indicated* [Fre]quently this is followed by rapid ret[urn] of flexion

TECHNIC

Regardless of the method employed [the] *maneuvers should be executed gently* [and] always under control of the surge[on] *Pump-handle*" methods are indefensi[ble] Complete muscular relaxation is a p[re]requisite this is achieved best by a gene[ral] anesthesia. Pentothol Sodium is a valua[ble] agent for this purpose The followi[ng] method is preferred by the author (F[ig] *220*)

The patient is placed on a table in [the] supine position and a general anesthe[tic] agent is administered The patient is th[en] drawn toward the foot of the table until t[he] *lower ends of the femora extend from 6* [to] *8 in* beyond the end of the table To man

ulate the right knee the surgeon places his left thigh with the foot, resting on a low stool, immediately in the popliteal space so that the patient's lower end of the femur and the upper end of the tibia rest on the anterior surface of his thigh Next he grasps the anterior surface of the lower thigh immediately above the patella with his left hand and grasps the patient's ankle with his right hand Flexion of the joint is achieved by making downward pressure on the lower leg at the same time that the femur is protected by downward pressure made by the surgeon's left hand and upward pressure made by his thigh. The pressure at all times should be steady and under control In some instances the resistance to flexion is suddenly released with an audible snap, and then the knee can be flexed completely with very little force In other cases a fine crackling is felt and heard throughout the entire manipulation In the latter cases one must assume that the loss of flexion is due to diffuse intra articular fibrosis Frequently manipulation of these cases is followed by severe tissue reaction which may terminate in more extensive fibrous tissue formation Better results are attained in such cases when repeated gentle manipulations are performed at intervals of 6 to 8 weeks In the former group, one manipulation usually suffices to initiate restoration of knee flexion

The success of manipulation therapy depends totally on the willingness of the patient to assume the responsibility of the execution of a stringent regimen comprising primarily active exercises designed to increase flexion and quadriceps power The manipulation per se is only the first step toward attainment of satisfactory flexion Cases which are not expected to produce severe postmanipulative reactions at the termination of the procedure are treated simply by the application of an elastic compression bandage and active motion on a regulated schedule is started the following day As a rule repeated manipulations are not required in these cases Physical therapy in the form of whirlpool baths, radiant heat and gentle massage to the muscles of the thigh and the calf add to the comfort of the patient Cases in which a violent tissue reaction is inevitable following manipulation are put at rest for 2 or 3 days The limb is fixed in a well padded posterior plaster splint, holding the knee within a few degrees short of the range obtained by manipulation, continuous hot fomentations are applied throughout this period of enforced rest. Generally, at the end of 2 or 3 days the acute reaction has subsided sufficiently to institute active motion at the knee joint Depending upon the tolerance of the patient, active exercises should be increased progressively in frequency and intensity The management is essentially the same as that described for cases of lesser severity If after 5 or 6 weeks of intensive therapy the range of motion is still not acceptable and further increase in the range of movement by conservative measures is not likely to occur, the manipulative process may be repeated Recently, in the severe cases, the author has injected Hydrocortone (1 cc) into the joint following the manipulation and every fourth day It appears that the joint reaction is not so severe, and motion returns with greater ease than in cases in which the agent is not employed Generally, 3 injections suffice

OPERATIVE MEASURES

As noted previously, the most significant factor blocking flexion following severe injuries such as fractures of the femur, is fibrosis in the deep components of the quadriceps Although, firm adhesions in the lateral expansions of the quadriceps mechanism and in the suprapatellar pouch may bind the patella to the femur, these are of secondary importance In such cases clinical assessment discloses that conservative and manipulative therapy are futile and that more radical means are necessary to attain a satisfactory range of flexion The

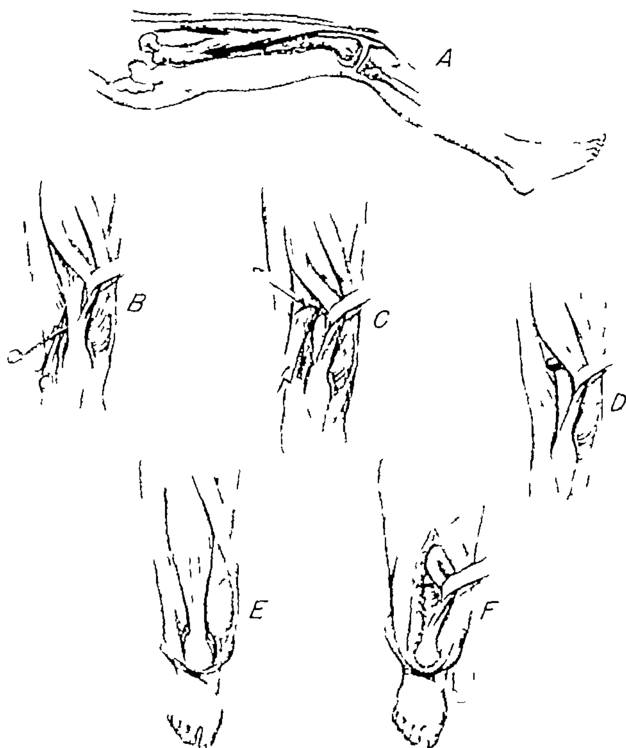


Fig 221 Thompson s technic of lengthening the quadriceps apparatus

more popular operations to increase flexion are those described by Bennett, Thompson McKeever and Smillie McKeever s procedure was designed primarily to prevent formation of adhesions following synovectomy As with manipulation the aforementioned surgical procedures do not ensure a satisfactory return of flexion without a concerted effort on the part of the patient to execute diligently a prescribed program conceived to restore an acceptable range of movement in the knee joint Without the co-operation and determination of the patient the best technically conceived opera

tion is doomed to failure. For cases with advanced scar tissue formation in the deep components of the quadriceps in which manipulation cannot overcome the barriers to normal flexion the author prefers Thompson s operation to increase flexion

Thompson s Quadricepsplasty Essentially, the procedure consists of excision of the scar tissue in the quadriceps muscle (as a rule the greater portion of the vastus intermedius is removed) and leaving the rectus femoris intact without lengthening it The procedure frees the remaining normal muscle tissue to function with minimum impediment The method is designed for cases having sustained severe injuries to the femur (particularly the lower third) or to the muscles of the thigh or to both without implication of the components of the joint. Compound fracture of the femur, especially those resulting from bullet or shrapnel injuries are frequently associated with marked disruption of the muscles and other soft tissues of the thigh. In these cases the extensive scarring in the muscles is the result of the original injury and also of the fibrosis incident to delayed healing and prolonged immobilization of the limb The presence of infection enhances still further the intensity of the fibroblastic process Pronounced loss of flexion is the rule in many of these cases Thompson points out that the degree of success in this operation depends upon an intact rectus femoris muscle, the degree to which it can be mobilized and freed from the scarred nonextensible portions of the quadriceps mechanism, and the extent to which the rectus femoris can be developed by active progressive exercises and normal use

Technic (Fig. 221) The extensor apparatus is exposed by an anterior incision which extends from the junction of the upper and the middle thirds of the thigh to the lower pole of the patella. After the fascia is exposed it is divided on either side of the rectus femoris from the upper third of the thigh downward parallelin~ the lateral margins of the rectus femoris The line of dissection on either side of the rectus femoris is continued deeply in the intervals between the rectus femoris an the vastus medialis and the vastus lateralis (Fig 221 B) This step should mobilize completely the rectus femoris from both vasti, next, the vasti are freed and permitted to fall toward their respective sides. The lateral intermuscular incisions are continued distally on either side of the patella, dividing the contracted capsule and the lateral expansions of the quadriceps aponeurosis (Fig 221 B) Usually, the vastus intermedius comprises a mass of dense mature fibrous tissue, binding firmly the under surface of the rectus femoris and the patella to the anterior surface of the femur (Fig 221 A) By sharp dissection the scar tissue is excised completely, this exposes the anterior surface of the femur except for a layer of fibrous and periosteal tissue (Fig 221 C, D) Occasionally, in cases with extensive fibrosis in the anterior aspect of the thigh resulting from compound wounds, it is necessary to reconstruct a rectus tendon by longitudinal cuts through the scar tissue situated in the distal third of the thigh At the termination of this step the rectus femoris is mobilized sufficiently and possesses enough elasticity (especially its upper normal position) to permit the leg to flex slightly beyond a right angle by gentle manipulation (Fig 221 E) The remaining intra-articular adhesions are overcome readily by this last maneuver

In the event that the vasti are not impaired seriously by scar tissue, they are attached to the margins of the rectus femoris as far distally as the junction of the middle and the lower thirds of the thigh the capsule of the joint is left open If the vasti are seriously damaged and scarred they are isolated from the rectus femoris by suturing the subcutaneous tissue and fat to the anterior surface of the femur, on one side or the other of the rectus (Fig. 221 F), this produces a new intermuscular

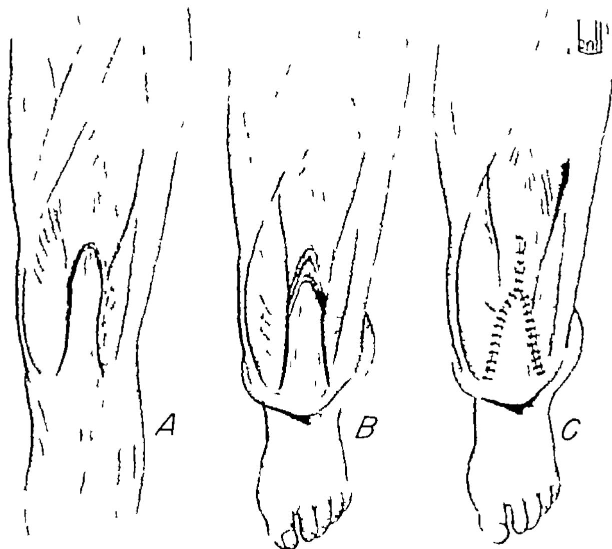


FIG 222 Bennett s method to lengthen the quadriceps apparatus

septum which separates the scarred muscle from the remaining quadriceps apparatus

The original technic may be modified at this point by interposing between the femur the scarred muscles and the rectus femoris some material which will preserve the gliding mechanism of the remaining extensor apparatus Cellophane has been used by some workers the author has employed nylon in one case which attained an excellent range of flexion Each case presents its own peculiar problems, and the technic must be modified accordingly Because the vastus medialis plays such a pertinent role in the over-all performance of the quadriceps every effort possible should be made to salvage and incorporate this muscle in the ultimate extensor mechanism reconstructed

POSTOPERATIVE MANAGEMENT At the termination of the operation an elastic compression bandage is applied and the limb is suspended in a Thomas splint with a Pearson attachment Active flexion and extension exercises are started immediately After 48 hours the compression bandage is removed and an Ace bandage is applied next to the skin except for a small sterile

gauze dressing covering the incision Exercises are performed under supervision on a regulated program and within the patient's tolerance of pain Many of these patients have as much as 90° flexion at the end of 3 weeks when they are removed from the suspension apparatus Ambulation is allowed on crutches, but weight bearing on the affected limb is not permitted for at least 3 more weeks Usually at the end of this period the strength in the extensor mechanism is sufficient to allow protected weight bearing without subjecting the supporting structures of the knee joint to abnormal strains incident to function

Bennett's Operation (Fig 222) In the hands of the author this procedure has not given the satisfactory results attained by the Thompson procedure Essentially, the quadriceps apparatus is lengthened by releasing the quadriceps tendon from all its muscular attachments and reattached to a lower level

TECHNIC A straight anterior skin incision is made from the junction of the lower and the middle thirds of the thigh to the middle of the patella the subcutaneous tissue and fascia are divided in the same line The quadriceps tendon is identified and released by longitudinal cuts on each side of the tendinous portion of the rectus femoris (Fig 222 A) The lateral incisions are deepened to include the tendinous portion of the vastus intermedius and to separate the combined rectus femoris and vastus intermedius from the vastus medialis and the vastus lateralis. At the level of the upper portion of the suprapatellar pouch the parallel incisions are jointed by a transverse incision (Fig 222 B) By sharp dissection the tendon mass is freed from the underlying tissue until it is detached completely Next an attempt is made to flex the knee joint all intra articular adhesions which tend to obstruct flexion are severed With the knee flexed fully the tendon is reattached to the surrounding muscles at a point approximately 1 inch or more below its original attachment (Fig 222 C) The postoperative management is similar to that described for Thompson's operation

Smillie's Method. This procedure is primarily designed for cases in which the scar tissue in the lateral expansions and in the suprapatellar pouch is of such a nature that it precludes manipulative methods to increase flexion at the knee joint. Also, the extent of fibrosis which is invariably present in the quadriceps is not of serious proportions In properly selected cases the procedure should increase the range of flexion from 45° to 90 Smillie warns against performing the procedure (1) in cases exhibiting an active pathologic process, (2) during the early stages of recovery (the range of motion must be stationary for at least 6 weeks), (3) in a joint still exhibiting local tissue reaction, such as swelling and increased local temperature, (4) in cases with demonstrable roentgenographic evidence of decalcification in the bony elements of the joint and (5) in cases of incomplete bony healing at the site of fracture in the femur

TECHNIC The operation is performed with a tourniquet applied high on the thigh and the extremity is draped separately to permit free manipulation of the leg by the surgeon. With the knee flexed to the limit of passive movement, the surgeon attempts to locate the site of the fibrous bands by manipulation After putting on a fresh pair of gloves, two parallel incisions are made on either side of the superior pole of the patella the incisions measure approximately 3½ to 4 cm The joint capsule is divided, and the index finger is inserted into the joint cavity first through one and then through the other incision, the adhesions extending to the femur and the tibia are localized by the palpating finger and then divided Next, the finger explores the suprapatellar pouch and adhesions found in this region are also divided With the completion of the last step usually the joint can be flexed to a right angle or be

yond Small friable adhesions are broken by the manipulation. The wound is closed in layers, and a compression bandage is applied, fixing the extremity in flexion just short of the arc obtained by the above operation Further immobilization is attained by the application of molded plaster splint to the flexor surface of the compression bandage. Now the tourniquet is released

POSTOPERATIVE MANAGEMENT Essentially, the postoperative treatment is similar to that described after manipulative methods are employed Smillie points out that the extent of improvement varies from 10° to 90°, depending upon the nature of the pathologic process and the co-operation and the endurance of the patient. If after a gain of 30° or 40° of flexion no further progress is attained, the procedure may be repeated

McKeever's Method. Following synovectomy, such as is performed in rheumatoid or mixed arthritis or in the cases of villonodular synovitis and osteochondromatosis frequently varying degrees of loss of flexion ensue In many cases the range of motion finally achieved represents the result of exhausting effort and determination on the part of the patient The block to flexion is not caused by fibrosis in the deep component of the quadriceps but is due to numerous firm adhesions in the suprapatellar pouch in the lateral compartments of the joint and in the lateral expansions of the quadriceps mechanisms The patellofemoral gliding mechanism is obliterated by adhesions binding the patella to the anterior surface of the femur McKeever points out that in such cases the insertion of an interposition membrane between raw surfaces modifies the formation of scar tissue so that adhesions of the two surfaces is present He is of the opinion that the purpose of the membrane is achieved in a few days, and if one desires it may be removed

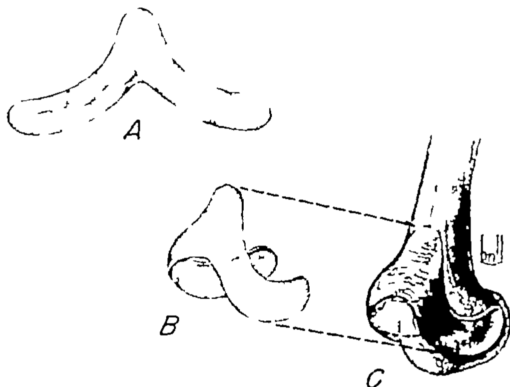


FIG. 223 D McKeever's method of preventing adhesions following synovectomy Cellophane or nylon may be used as the interposition membrane

In the series reported by this worker the membrane was left in situ, cellophane was used as the interposition membrane

Technic (Fig 223) The joint cavity is exposed through a medial parapatellar incision, and a synovectomy is performed in the usual manner A piece of cellophane, previously sterilized in an autoclave, is cut in a pattern to fit the suprapatellar pouch and extends laterally and medially on either side of the femoral condyles beneath the collateral ligaments where they cross the joint space (Fig 223 A, B, C) Fixation of the membrane is not deemed necessary The wound is closed in layers, and a compression bandage is applied

A strict postoperative program in rehabilitation was not instituted in McKeever's case In all cases a rapid and satisfactory restoration of flexion and powerful extension ensued These results have prompted the author to use nylon as the interposition membrane following synovectomy in the last 8 cases The membrane is made secure by fine interrupted cotton sutures A rapid return of painless motion was noted in each instance The postoperative management in these cases was facilitated by placing the limb in balanced suspension in a Thomas splint with a Pearson attachment. In addition, Hydrocortone (1 cc.) was injected into the suprapatellar pouch at the termination of the operation and a regulated regimen of progressive exercises was instituted Hydrocortone was instilled into the joint every third day following the operation for 3 injections

FLEXION CONTRACTURES FOLLOWING INJURIES TO OR IN THE REGION OF THE KNEE JOINT

Flexion contractures of varying degrees are prone to occur following injuries to the knee joint, fractures in, above or below the knee joint and intra articular surgical procedures. Deformities following surgical procedures such as meniscectomy or exploratory incisions can be prevented by maintaining at all times quadriceps power at a high level of efficiency It is true that some atrophy and loss of power of the extensor apparatus is inevitable after every operation on the knee joint nevertheless by judicious exercises before and after the operation the amount of power lost is maintained at a minimum, and restoration to normalcy is achieved rapidly Clinical experience teaches that rapid development of the quadriceps, particularly the vastus medialis, is the prime single factor in prophylaxis of flexion deformities and in cases of short duration before permanent tissue alterations have occurred, this same factor is of utmost importance in overcoming the deformities Loss of extension is also encountered frequently following synovectomy of the knee joint Here as above the same factors prevail, except that the subsequent fibrosis in the suprapatellar pouch and the lateral compartments of the knee may restrict the normal excursion of the patella, producing limited flexion and extension short of 180° Here, as in the case of other operative procedures, early restoration of quadriceps control and power is essential as a preventive and corrective measure Prolonged immobilization of the knee in varying degrees of flexion for fractures implicating the femur or the tibia is a common causative agent for flexion deformities. As noted in the chapter dealing with the specific fractures, immobilization of the knee must be maintained no longer than is necessary to ensure stability of the fragments if continued beyond this point, resistance and permanent deformities may be the penalty

Not infrequently deformities are caused by incorrect positioning of the limb in bed following a surgical procedure of the knee Placing a pillow under the knee joint is a common error Also the author has observed many times loss of extension in the knees of elderly people who for some reason not related to the joints are confined to bed

for several weeks Most of these patients have varying degrees of degenerative alterations in the knee joint If through neglect they are allowed to assume positions of flexion contractures of the knees may result

Management of Early Flexion Deformities

As previously recorded in the majority of operative cases loss of extension can be prevented by proper management and understanding of the significance of a powerful vastus medialis in the role of the extensor mechanism When early cases are encountered in which as yet no structural shortening of the posterior tissues and muscles have occurred often a program of intensive quadriceps exercises against increasing loads will overcome the flexion contracture Those cases which fail to respond may be corrected by traction of the Buck s extension type to this is added the aforementioned quadriceps regimen.

Cases of longer duration may not be amenable to these simple conservative measures The degree of fibrosis and shortening which has occurred in the posterior tissues is sufficient to resist the action of the extensor apparatus and even traction These cases may be corrected by manipulation under anesthesia followed by the application of a posterior molded plaster splint to retain the correction After the reaction of the manipulation has subsided quadriceps exercises against increasing resistance are begun The posterior splint is maintained until the quadriceps is sufficiently strong to preclude a recurrence of the deformity

Resistant Flexion Deformities

The alterations in the posterior portion of the capsule hamstring muscles and fascia lata may be advanced to the point that the aforementioned methods may not be effective When the deformity has existed for a prolonged period contracture of the biceps femoris and the tensor fascia lata may increase the normal deviation of the knee and force the tibia into a fixed position of external rotation. In addition varying degrees of posterior subluxation of the tibia may be present

Regardless of the causative agent in resistant cases without posterior subluxation of the tibia the author attempts to regain full extension by the turnbuckle cast described by Kulowski The method is described on page 568 Flexion deformities with posterior subluxation or those which fail to respond to the turnbuckle cast method are treated by surgical measures the posterior subluxation is corrected by compound traction The operative methods are described on page 570 these comprise posterior capsulotomy or Wilson s posterior capsuloplasty

Yount pointed out the role that contracture of the tensor fasciae femoris muscle plays in the development of flexion deformities of the knee it may produce abduction and external rotation of the tibia on the femur and abduction and flexion deformities of the hip These deformities are especially prone to develop in cases of residual poliomyelitis Except in severe deformities and in those of longstanding the abduction and the flexion contractures of the hip and flexion deformity of the knee may be corrected by releasing the iliotibial band at the knee The technic is described on page 330

Osteotomy to Correct Flexion Deformities

As previously noted every effort should be made to restore complete extension of the knee joint by the aforementioned methods recorded Occasionally a serviceable range of flexion is present beyond the point of the flexion deformity and yet conditions prevail which preclude correction by stretching or lengthening the soft tissue structures A typical example would be a child with a flexion contracture following

severe scarring due to extensive burns in the region of the popliteal space. In such instance some type of osteotomy in the supracondylar region of the femur is justifiable This improves the alignment and the functional capacity of the limb The various types of osteotomies are discussed subsequently in this section

Arthrodesis and Arthroplasty of the Knee Joint

Severe trauma to the soft tissues and to the cartilaginous and the osseous elements of the knee joint may result in severe intraarticular changes which preclude useful function a fibrous or osseous ankylosis may be the ultimate result. Frequently in such cases a choice between arthrodesis and arthroplasty must be made The indications justifying these procedures and the contraindications are discussed in Chapter 13 "Surgical Approaches and Procedures."

Bony Ankylosis of the Knee in Flexion

Bony ankylosis of the knee in a position of flexion may be a complication of severe trauma to the knee joint, rheumatoid arthritis, pyogenic arthritis, osteomyelitis or tuberculosis. The general alignment of the extremity may be improved by performing a supracondylar osteotomy This procedure does not irradicate the deformity but establishes a compensatory angulation above the knee opposite to the existing angulation at the level of the joint As will be noted subsequently, this same principle is employed occasionally in flexion contractures following spastic paralysis or poliomyelitis, or in genu varum or valgum deformity caused by rickets or growth disturbances following fractures or osteomyelitis Supracondylar osteotomies performed in children should be proximal to the epiphyseal plate in order to preserve the integrity of this structure

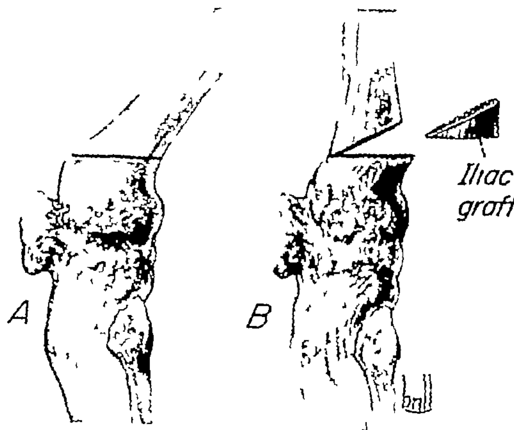


Fig 224 (A) Open wedge osteotomy to correct a flexion deformity at the knee joint. (B) The triangular piece of bone is obtained from the crest of the ilium and is inserted into the defect.

which, if injured may cause some impairment of growth. The amount of correction permissible is governed by the degree of contracture of the soft tissues If the resistance offered by these structures cannot be overcome by stretching tenotomy of the hamstring muscles is justifiable Overstretching of the vessels and the nerves must be avoided This can be achieved best by performing a type of osteotomy which shortens slightly the extremity Thompson s telescoping V-osteotomy is such a procedure Before any type of osteotomy is executed *surgically a careful analysis* should be made of the tracings made from teleoroentgenograms of the bony components of both extremities This study should disclose the functional and mechanical axis of the limb, the true and functional shortening of the limb as a whole, the site and the degree of the deformity and the presence of *compensatory deformities* above or below the primary angulation From this information one is able to decide the site and the type of the proposed osteotomy the expected amount of lengthening or shortening of the limb and whether or not the extent of stretching in the soft tissue subsequent to the operation will allow the desired correction. When the soft tissues preclude full correction plans must be made to compromise with a partial correction at the *initial operation with the reservation that* lengthening of the soft tissues must be achieved at a second operation before the desired correction is attained

Open Wedge Supracondylar Osteotomy (Fig 224)

This type of osteotomy tends to put the soft tissues on the posterior aspect of the knee on considerable stretch because it increases slightly the length of the limb (Fig 224) *In deformities exceeding 135° to 140* release of the hamstring tendons by doing tenotomies prior to the osteotomy facilitates correction of the deformity

Technic. A longitudinal skin incision 2 to 3 inches long is made on the lateral aspect of the thigh beginning just proximal *to the lateral femoral epicondyle* The incision is deepened through all layers to the bone By blunt dissection the periosteum is stripped from the entire circumference of the bone so that an intact periosteal tube surrounds the osteotomy site With a sharp thin osteotome at the desired site the posterior two thirds of the femur is divided The deformity is corrected by manual force, which produces a greenstick type of fracture in the remaining anterior third of *the femur* In order to retain the desired correction, a triangular graft of full thickness of iliac bone is wedged between the fragments as depicted in Figure 224 B In adults division of the bone is facilitated by drilling several holes through the lateral and the medial cortex of the femur in the line of the osteotomy This step prevents shattering of the bone when the osteotome is driven through the shaft of the femur Also in adults if the surgeon desires rigid *fixation of the fragments in order to* preclude loss of correction and to ensure rapid bony healing a Blount blade plate may be used to achieve this end. Of course, if a blade plate is employed the wound must be extended proximally and distally in order to provide adequate exposure The wound is closed in layers The desired position of the extremity is maintained by a plaster spica extending from the costal cage to the toes on the affected side

Postoperative Management. If roentgenograph studies disclose that a change in position of the fragments is desirable this can be achieved by wedging the cast at the level of the osteotomy As a rule immobilization in plaster must be continued from 8 to 10 weeks at the end of this period the cast is removed, and a brace is applied without a joint at the knee The limb must be protected by a brace until bony healing is sufficient to ensure against *recurrence of the deformity* this usually means a period of several months

CUNEIFORM SUPRACONDYLAR OSTEOTOMY (Fig 225)

This type is usually employed in adults with severe flexion contractures (90 or less) Some shortening is accepted, but the vessels on the posterior surface of the femur are less likely to be stretched unduly Also, this method brings into apposition a large surface area of the proximal and the distal fragments.

Technic. The desired site of the osteotomy is exposed by a longitudinal incision on the lateral aspect of the thigh, beginning at the level of the external epicondyle of the femur and extending proximally for a distance of 3 to 4 inches The skin incision is deepened to the bone, and the periosteum is stripped with a blunt elevator All soft tissues, anteriorly and posteriorly, are retracted from the bone by Bennett retractors, providing adequate exposure of the osteotomy site A wedge shaped piece of bone is removed from the anterior position of the femur with its base anteriorly and its angle measuring approximately one half that of the flexion deformity (Fig 225 A) By closing the defect, the deformity is corrected, and the raw surfaces of the proximal and distal fragments are brought in apposition (Fig 225 B) As in the open wedge type of osteotomy, rigid fixation may be attained by the use of a Blount blade plate At the termination of the operation a plaster spica is applied, extending from the costal margins to the toes The postoperative treatment is similar in every feature to that described following the open wedge osteotomy of the femur

CIRCULAR OSTEOTOMY (Fig 226)

A circular osteotomy as described by Codivilla ensures maintenance of the corrected position This method creates a convex surface on the proximal fragment and a concave surface on the distal, allowing the lower end to swing like a pivot and at the same time permitting apposition of the large areas of the two fragments

Technic. The bone is exposed by a longitudinal incision 3 to 4 in in length on the lateral aspect of the thigh, beginning at the level of the external femoral epicondyle The periosteum is stripped from the bone and retracted anteriorly and posteriorly with the surrounding soft tissues With a

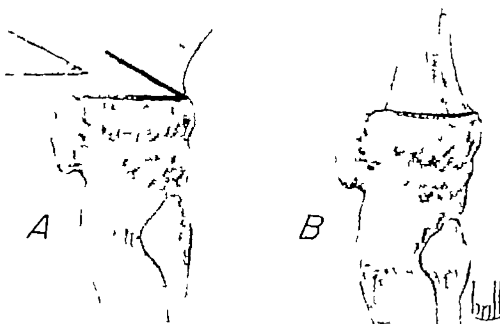


FIG. 225 Cuneiform supracondylar osteotomy

fine osteotome ¼ in wide, a circular osteotomy is performed removing a minimal amount of bone (Fig 226 A, B) After the maximum correction is attained without unduly stretching the neurovascular structures a plaster spica is applied from the costal margins to the toes

Postoperative Management. If the desired correction (10° to 15° short of full extension) is attained, immobilization in the plaster spica is continued from 8 to 10 weeks The subsequent treatment is similar to that recorded following open wedge osteotomy In cases with severe flexion deformities satisfactory alignment may not be attainable without jeopardizing the muscles and the nerves on the posterior aspect of the knee It becomes apparent that supplementary measures are necessary to complete the correction. In this event after the operation is completed one must be satisfied with only partial correction of the deformity the limb is encased in a plaster spica, holding this position From 10 to 14 days later tenotomies and a posterior capsulotomy of the hamstrings are done and a turnbuckle cast is applied After the operative reaction has subsided the deformity is corrected slowly until satisfactory alignment is obtained The turnbuckle cast is maintained for 4 weeks then the limb is fixed in another cast until there is roentgenographic evidence of bony ankylosis this usually means a period of 4 to 6 weeks more The extremity is further protected by a brace without a joint at the knee This is worn until bony ankylosis is sufficiently strong to prevent recurrence of the deformity

Both the cuneiform and the circular osteotomies may be employed at the apex of the flexion deformity which usually corresponds to the level of the old joint line Correction at this level results in more anatomic alignment of the upper and the lower parts of the leg If the operations are

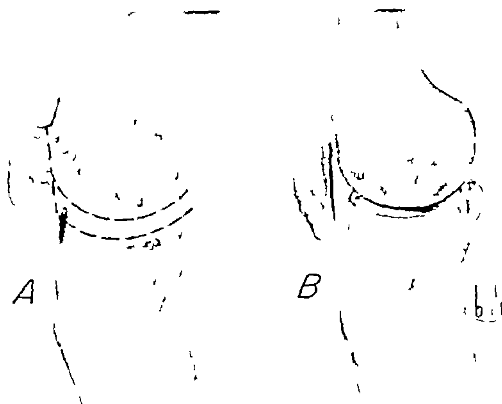


Fig 226 Circular supracondylar osteotomy

performed in children, care must be employed not to traumatize the epiphyseal plates such a complication will result in disturbance of growth. The technics are similar to those described for the supracondylar osteotomies, except that more exposure is necessary to perform the operation A median parapatellar incision extending proximally along the medial border of the vastus medialis, supplies ample exposure After the bony fusion between the patella and the anterior surface of the femur is divided, the lower end of the femur is exposed by blunt subperiosteal dissection and the soft tissues are retracted away from the bone by Bennett retractors

If a circular osteotomy is the operation of choice, the line of division may conform to the outline of the normal configuration of the femoral condyles This type is especially useful in moderate flexion deformity because only minimal stretch is put on the neurovascular structures when optimum correction is attained For more severe flexion deformities, a cuneiform osteotomy is preferred, a wedge of bone is removed with its base anteriorly

The postoperative management is similar to that described for the supracondylar osteotomies

TELESCOPING V-OSTEOTOMY (Fig 227)

In 1943, V P Thompson described this procedure which was designed to correct angular and rotational disalignment in bone which is conoidal in longitudinal section it is readily adaptable to ankylosis of the knee in flexion Essentially, the proximal fragment is telescoped into the cancellous bone of the distal fragment. In severe deformities a small portion of the distal fragment is removed this results in slight short

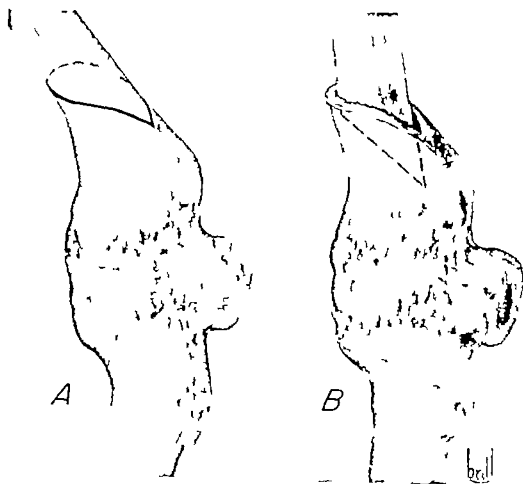


FIG 227 Telescoping V-osteotomy (V P Thompson)





FIG 228 (A *Left*) Male, aged 21 with ankylosis of the right knee in severe recurvatum (B *Right*) Roentgenogram of the knee depicted in A Note the presence of a wire. The reason for its use was never established

ening of the limb but the posterior vessels and nerves are not subjected to harmful tension. Telescoping one fragment into the other provides excellent contact of the bone ends and also good stability Bony healing is assured and prompt

Technic. The anterior surface of the femur is approached by a medial parapatellar incision the bone is exposed by blunt subperiosteal dissection and all soft tissues are retracted away from the bone by Bennett retractors A V-osteotomy is performed on the anterior surface of the femur with the apex directed toward the metaphysis the arms of the V pass obliquely away from the metaphysis the posterior cortex may be sectioned transversely or in young individuals it may be partially severed and allowed to function as a hinge (Fig 227 A) The pointed fragment is beveled slightly so that it readily telescopes into the cancellous bone of the distal fragment (Fig 227 B) In cases with severe flexion deformities it may be necessary to excavate the metaphyseal fragment in order that it may receive the pointed fragment Occasionally small wedges must be removed from the pointed end to effect a proper fit this is especially indicated in severe flexion deformity in which some shortening is desirable in order to prevent undue tension on the vessels and the nerves located posteriorly

The postoperative management is similar to that recorded for other supracondylar osteotomies



Fig 228 (C) Deformity was corrected by two open wedge osteotomies the wire was not disturbed healing at the osteotomy sites is discernible (6 months postoperatively)



Fig 228 (D) Unusual case of tibia retroversa in a female, aged 11 The deformity followed a fracture through the upper end of the tibia at the age of 7

BONY ANKYLOSIS OF THE KNEE IN RECURVATUM

Occasionally, bony ankylosis is encountered with the knee joint in varying degrees of recurvatum The same principles are employed as those discussed in the section dealing with ankylosis in flexion

The author encountered an unusually severe case of ankylosis in the position of recurvatum in a male 21 years of age. From the patient's story, it was concluded that the deformity developed after a pyogenic infection of the knee joint at the age of 4 years The deformity gradually increased and on March 5 1952, he presented the deformity depicted in Figure 228 The hip joint of the same extremity was not affected the foot was in 20° of equinus Because of the severe posterior angulation of the leg it was decided to perform two open wedge osteotomies, one above and one below the site of maximum angulation By these procedures, complete correction of the limb was achieved Figure 228 C shows the correction attained.

ANGULAR DEFORMITIES

Angular deformities in and about the knee joint are encountered frequently. The causative agents are numerous. Some are apparent, such as trauma producing closure of a portion of the epiphyseal plate or metabolic and nutritional disorders as rickets, which in the past has been responsible for a large majority of acquired deformities of knee joints. Some deformities observed in infancy or early childhood may be on a hereditary or congenital basis, others are definitely associated with endocrine disturbances or follow in the wake of some infectious process. Static abnormalities of bones and joints play a role in some instances, as does muscle imbalance such as is encountered in spastic paralysis and infantile paralysis. On the other hand, the etiologic factors in a certain group of cases are speculative and highly controversial.

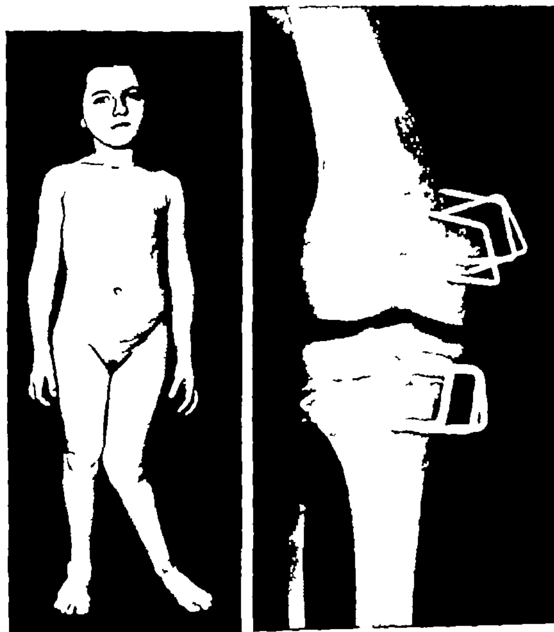


Fig 229 (A *Left*) Genu valgum of the left extremity. Observe the external rotation of the tibia on the femur due to traction of the biceps femoris and the tensor fascia femoris muscle (etiology is not known). (B *Right*) The patient was treated by stapling the femoral and the tibial epiphyses.

This is especially true in disturbances of growth of the lower femoral and upper tibial epiphysis which resemble in a large measure osteochondrosis tibia vara is an example of these disorders

Although angular deformities can occur in any plane, the majority are either in the coronal or the sagittal planes Valgus and varus deformities are in the coronal plane, while recurvatum of the knee and the rare tibia retroversa deformity are in the sagittal plane (Fig 228 D) The observations of Milch are helpful guides in choosing the correct site of correction and in the selection of cases amenable to surgical intervention This observer points out that a deformity can be corrected only when the osteotomy is performed at the site of maximum deformity or the apex, this allows restoration of length of the bone and normal alignment of its articular surfaces. In the normal tibia the articular surfaces are parallel with each other and perpendicular to its longitudinal axis, in tibia vara the superior and the inferior articular surfaces converge medially, while in tibia valga they converge laterally The angle of convergence may be larger or smaller than the angle of the deformity, the angle of correction never should be greater than the difference between the angle of deformity and the angle of convergence This measurement is best attained from tracings of teleoroentgenograms In uniaxial deformities implicating the tibia regardless of the type the shaft of the bone is concave on the side toward which its articular surfaces converge As a rule these deformities can be corrected by an open wedge osteotomy on the concave side This tends to lengthen the bone The same correction may be ob



Fig 229 (C *Left*) The correction attained 2 years after stapling (D *Right*) Roentgenogram of the extremity shown in C the staples have been removed

tained by removing a wedge of bone on the convex or longer side of the bone this procedure tends to shorten the length of the deformed bone In some cases the latter procedure is more desirable than the former because it puts minimal traction on the tissues on the outer side of the knee joint especially on the peroneal nerve

Genu Valgum

Essentially, the deformity comprises an inward projection of the knee joint and a lateral deviation of the leg in relation to the longitudinal axis of the femur forming an outward angle of varying degrees In severe cases of longstanding traction of the biceps femoris muscle and the tensor fascia femoris muscles tend to rotate the tibia outward on the femur In addition, the tibia may develop a compensatory varus deformity also the distal end of the femur may develop an outward twist (Fig 229 A)

Etiology As noted previously numerous etiologic factors may produce this angular deformity at the knee joint Static abnormalities are frequent causes notably among these are pronated and flat feet and obesity Although at one time rickets was believed to be frequently responsible for valgus and other deformities of the knee now it is recognized that rickets like all other malacic bone disorders is not the primary causative agent however these lesions are predisposing factors. Congenital and hereditary factors may be responsible for the disorder Trauma to the epiphyseal cartilage plate may result in disturbance of growth which culminates in varying degrees of deviation at the knee joint

The work of Abbott and Gill on this deformity resulting from injury to the lower femoral epiphysis has brought to our attention many significant observations relative to the pathogenesis and the *treatment of* this disorder these observations are recorded herein Disturbed growth may be the direct result of crushing injuries to the epiphyseal plate or to the epiphysis In young children these injuries usually are produced by a fall from a height In rare instances *shearing injuries may produce* fractures of the epiphyseal plate or the epiphysis in older children The resulting deformity is governed by the area of the epiphyseal plate damaged hence several types of angular deformities have been observed as genu varum genu valgum genu recurvatum and even total cessation of growth. Of *these genu valgum is encountered* most frequently in this lesion the lateral portion of the epiphyseal cartilage plate of the femur is damaged severely Several factors are responsible for the higher incidence of valgus deformities over other types of angular deformities These are the normal deviation of the knee and the vulnerability of the lateral aspect of the knee to trauma When a child falls from a height and lands on the feet the normal deviation of the knee tends to force the body weight against the lateral portion of the epiphyseal plate thereby crushing this region of the structure Occasionally a fracture of the femur may also ensue in this event the injury to the epiphyseal plate may not be recognized until a valgus deformity manifests itself

Subsequent to injury of the cartilage plate healing may terminate with the formation of a bony lock between the lateral portion of the epiphysis and the diaphysis. The bony lock now functions as a fixed point while the medial portion of the plate continues to grow downward and in a circular direction The severity of the valgus deformity is governed by the location of the bony lock and by the age of the patient Severe deformities develop in young children while in the age group close to skeletal maturation minimal or no deformities evolve Of interest is the gradual *extension of the bony lock* during growth from the lateral to the medial side of the epiphyseal plate so that the medial condyle on the affected side never attains the size of the medial condyle on the normal ex

tremity With closure of the medial side of the plate the configuration of the deformity is fixed Because there is a premature closure of the medial portion of the plate, inequality in leg lengths ensues Functional length of the limb, which is measured by a straight line from the head of the femur to the medial malleolus, becomes less as the angle of the valgus deformity increases. Children with severe valgus angulations the onset of which dates to early childhood also exhibit a compensatory deformity in the tibia in the opposite direction. This varus deformity in the tibia is the product of abnormal weight bearing stresses created by the severe deviation of the femur

The range of motion at the knee joint is not significantly impaired This is explained by the observation that the deformity does not disturb the development of the articular surfaces of the femur, however the plane of motion at the joint in relation to the longitudinal axis of the femur is seriously altered With the change in alignment of the bony elements at the knee joint there is a concomitant alteration in the functional axes of the muscles crossing the joint The quadriceps tends to displace the patella laterally In addition, the soft tissue supportive structures on the medial aspect of the knee are relatively lax, while those on the lateral aspect are shortened the peroneal nerve is included in the soft tissue alterations. The fibular collateral ligament exhibits some laxity in severe cases this is due to the effort that the patient makes continuously to adduct the leg on the femur in order to place the foot squarely on the ground when walking

Clinical Features. Mild degrees of genu valgum are observed frequently in children under the age of 5 years in the majority of cases the disorder is physiologic and not associated with bony endocrine or dietary disorders. If the lesion develops subsequent to trauma to the epiphyseal cartilage plate in young children the deformity manifests itself 3 or 4 months after the injury, with growth, the angular deformity increases progressively in gradient. The normal child under the age of 5 years stands with the medial femoral condyles and the internal malleoli in close proximity, almost touching On the other hand, children with knock knees stand with the medial femoral condyles touching and the internal malleoli separated In walking, the knees rub together The line of weight-bearing no longer passes through the center of the knee joint but is shifted to the outer side This is responsible for an awkward lurching gait. During function the supportive tissues of the knee joints are subjected constantly to abnormal stresses which produce laxity of the structures and chronic synovitis When the knee is fully flexed in nontraumatic cases the deformity disappears because in this position the tibia articulates with the posterior portions of the condyles which are not affected.

Treatment. Mild cases in growing children often respond to simple conservative measures A shoe correction comprising a medial heel and a sole wedge (from 1/8 in to 1/4 in, depending on the age of the child) tends to restore the normal line of weight bearing and correct the pronation of the feet, which is usually a concomitant disorder Manipulation enhances improvement. If the right leg is to be manipulated, the distal end of the femur immediately above the condyles is grasped firmly with the left hand, and the right hand grasps the leg just above the malleoli, the leg is then forced repeatedly into adduction These maneuvers tend to stretch the contracted soft tissue structures in the lateral aspect of the leg and subject the medial femoral condyle to mild intermittent pressure. Night splints may be worn In more resistant cases knock knee braces are indicated More severe cases, in which trauma is not a causative factor and no bony lock of the lateral portion of the distal epiphyseal plate of the femur exists, require some form of surgical

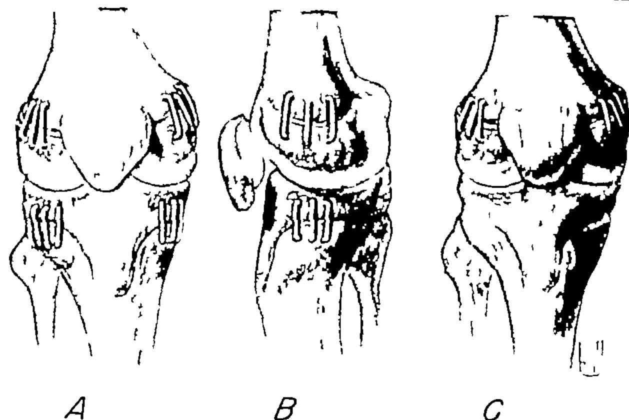


FIG 230 Position of staples Three staples comprise a unit (A, B) Both epiphyses are stapled if both the femur and the tibia are too long (C) If the femur is too long only its distal epiphysis is stapled. Note the position of the staples in relation to the undulating epiphyseal plates. (Redrawn from Blount)

intervention The most efficient procedures to correct angular deformity are stapling and osteotomy at the site of maximum deformity

STAPLING By this method the growth of the medial hemiepiphysis is retarded for a period sufficiently long to allow correction of the valgus deformity Haas (1945) was the first to show that temporary retardation of growth was possible by the use of a wire loop However in 1862 Heuter noted that bone structures under diminished compression exhibited greater growth than those under more compression Later Volkmann observed that abnormal unequal compression resulted in asymmetric growth of a joint retardation of growth was more marked on the side subjected to the greater pressure These observations comprise the basis for epiphyseal stapling Blount and Clark popularized the use of staples to correct linear and angular deformities and designed the operative technic employed about the knee joint The observations of these workers are recorded herein Stapling should be utilized while sufficient growth potential still remains to allow correction of any inadvertent angular deformity To obtain almost complete cessation of growth three staples should be used in a unit (Fig 230) If one staple is inserted on each side of an epiphysis it will bend or break If two are inserted they will bend and occasionally break Timing of the insertion and the removal of the staples is important they should be inserted early enough before growth is completed to permit correction of the deformity to take place but not in children under 8 years of age and they should be removed when correction is achieved Removal of the staples at the correct time is imperative when they are

inserted to correct angular deformities, failure to do so may result in the formation of inadvertent deformities The need of careful, frequent follow up evaluations of the affected limb becomes apparent.

Technic for Correction of Valgus Deformity (Blount and Clarke)

After a tourniquet is applied at the level of the mid thigh and the limb is draped sandbags or a block are placed under the knee, flexing it from 30° to 70° An oblique skin incision 5 to 8 cm long is made on the medial aspect of the distal end of the femur and is centered over the epiphysis the incision slants from anterior-proximal to posterior-distal The subcutaneous tissue is divided in the line of the skin incison and the deep fascial layers are split in the direction of their fibers Retraction on the margins of the fascial layers exposes the vastus medialis, which is now displaced anteriorly while the hamstring tendons are displaced posteriorly, the intervening fascial layers are split in the direction of their fibers With the knee extended and the vastus medialis displaced anteriorly, the anteromedial segment of the epiphyseal plate becomes accessible by flexing the knee joint acutely the posterior portion of the femoral condyle is reached readily

The staples may be inserted "blind" however the author prefers to expose the epiphyseal plate A longitudinal incision, approximately 1 in in length is made through the periosteum and the cartilaginous cap, at each end of this incision short crosscuts are made With a thin sharp osteotome two longitudinal flaps are elevated under which the epiphyseal cartilage plate is readily discernible It is essential to center the staples accurately in an anteroposterior direction failure to achieve this may result in a recurvatum deformity if the staples are placed too far anteriorly or the opposite deformity if they are placed too far posteriorly

It is important to bear in mind that the epiphyseal plate of the femur and the tibia undulate In the femur, Blount and Clarke point out that to ensure maximum efficiency, the center of the crosspiece of the staples should be slightly distal to the epiphyseal plate the anterior and the posterior staples should be placed slightly proximal to the middle one (Fig 230) In extreme cases of valgus deformity both the femoral and the tibial epiphyses may be stapled (Fig 229 B) In this event the oblique incision below the knee slants from posterior proximal to anterior distal splitting the anterior fibers of the pes anserinus The sartorius and the gracilis are retracted posteriorly in order to reach the anterior and the medial aspects of the epiphysis The epiphyseal plate is exposed by a longitudinal incision with crosscut at each end the longitudinal flaps are raised and the plate is exposed In the tibia the staples are inserted so that the center of the staple is slightly proximal to the epiphyseal plate

Before the wounds are closed, roentgenograms in both the anteroposterior and the lateral planes are taken. Staples placed incorrectly are removed and reinserted The position of the staples is checked again by roentgenograms The wound is closed in layers and a plaster cylinder is applied from the groin to the ankle in young children the foot is also included All operative reaction usually subsides within 2 to 3 weeks the patient is now allowed to bear weight on the extremity, either with or without crutches

Following the principles laid down by Blount and Clarke the author has had some very gratifying results in the treatment of angular deformities about the knee joint and discrepancies in leg lengths by controlling epiphyseal growth by stapling procedures On the other hand the final word on this method has not yet been written more information is desired relative to the indications and the contraindications of the method This knowledge can be attained only by long term follow up studies as

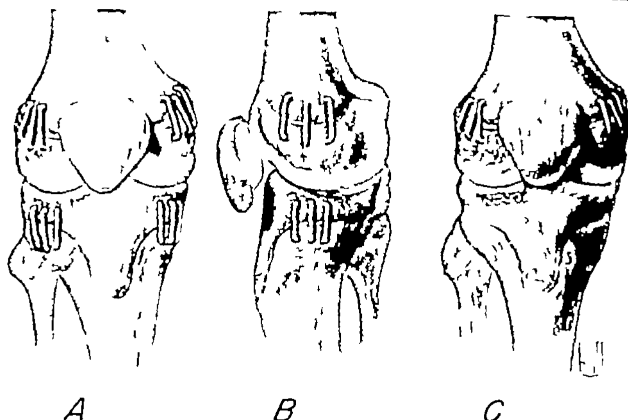


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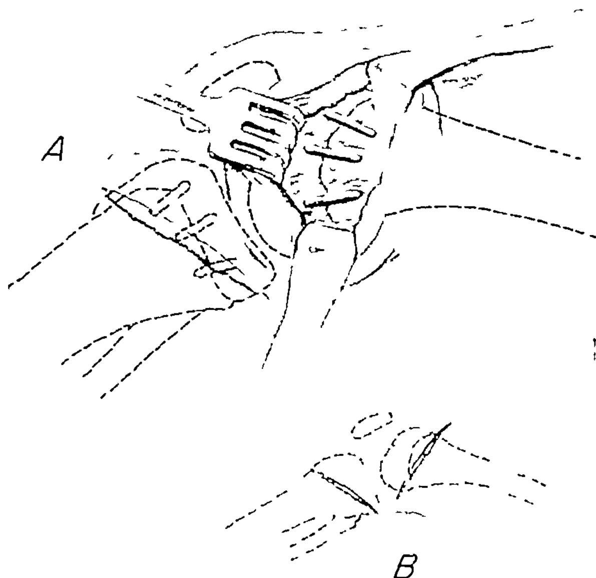


Fig 231 Incisions (Blount and Clarke) to expose the medial and the lateral aspects of the femoral and the tibial epiphyses (A) medial incisions (B) lateral incisions

yet these are not available hence this *method should not be employed indiscriminately and above all should not be preferred* to methods which have weathered the test of time However sufficient evidence is available to indicate that stapling will find a permanent berth in the armamentarium of the orthopedic surgeon for the treatment of inequalities of leg lengths and *angular deformities in growing children*

Stapling for Linear Deformities

For linear deformities temporary arrest of growth of the distal femoral and the *proximal tibial epiphyses may be achieved by stapling The staples are retained until* the equality of length is attained The observations recorded previously in discussing the treatment of angular deformities by stapling are applicable to the problems of linear deformities In some cases due to overgrowth the epiphysis of one bone either *the femur or the tibia is stapled In other* cases overgrowth may implicate both bones such as in hemihypertrophy here both epiphyses are stapled (Fig 206) Of course

instances of an abnormal shortening of one extremity usually necessitates retardation of growth of both the epiphyses in the region of the knee joint of the opposite extremity As noted previously, a unit of three staples is essential to prevent the development of angular deformities

The epiphyseal plates are best exposed by 2 medial and 2 lateral incisions (Fig 231) The 2 proximal incisions are directed from anterior-proximal to posterior-distal the 2 incisions below the knee joint slant from posterior-proximal to anterior-distal The exposures of the epiphyseal plates are similar to those recorded in the discussion dealing with angular deformities. In addition, the proximal fibular epiphyseal plate is exposed by subperiosteal dissection on the anterior aspect of the upper end of the fibula, and the peroneal nerve is identified and retracted to one side One half or more of the epiphyseal plate is excised with a sharp thin osteotome, and the defect is packed with bone chips obtained from above and below

Osteotomy at Site of Maximum Deformity

As recorded previously, correction of valgus deformity is achieved best by performing an osteotomy at the site of maximum deformity, which may be either in the tibia or the femur An osteotomy at this site ensures correction of the deformity, increases length of the osteotomized bone and in the case of the tibia restores normal relationship of its superior and inferior articular surfaces The most practical type is the cuneiform wedge osteotomy This may be achieved by one of two methods (1) a wedge of bone is resected from the medial site of the femur or the tibia, depending on the site of maximum deformity and (2) a wedge is opened on the lateral side The former procedure is accompanied by some shortening of the osteotomized bone and may be employed in growing children in whom length is of no particular significance or in cases in which contracture of the soft tissues on the outer side of the deformity jeopardizes the integrity of the peroneal

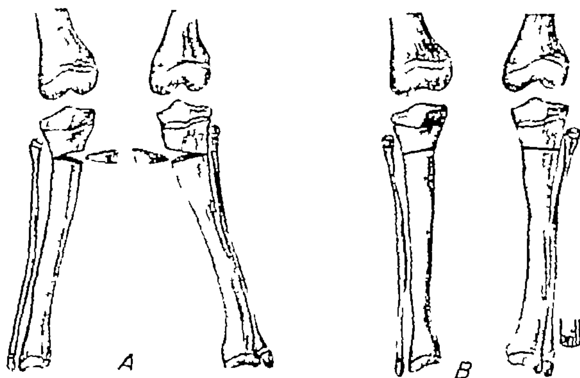


Fig 232 Correction of bilateral valgus deformity (A) a wedge of bone is resected from the medial side of the tibia, (B) the deformity is corrected with slight shortening of the tibia

nerve The latter method tends to increase bone length and is especially indicated where an increase in length is desirable. In this event, occasionally, it may be necessary to lengthen the soft tissue element on the lateral side and transplant the peroneal nerve to an anterior position In the femur unless there are special indications to the contrary the author prefers an open wedge osteotomy on the lateral side of the bone and in the tibia resection of a wedge of bone on the medial side (Fig 232)

In all instances before operation it is imperative to emphasize that tracings of teleoroentgenograms be made and studied carefully in order to determine the exact site of the osteotomy and the amount of correction desired

Open Wedge Osteotomy In idiopathic cases of valgus deformity in which the distal end of the femur is implicated a transverse linear osteotomy is made at the site of maximum deformity on the lateral side of the femur and a wedge is opened forcing the distal fragment medially

A longitudinal incision 1½ to 2 in long is made on the lateral aspect of the thigh immediately above the level of the lateral condyle The incision is deepened to the bone which is exposed subperiosteally A sharp thin osteotome is driven three fourths of the diameter of the bone Then the leg is displaced medially thereby opening a wedge at the site of the osteotomy In order to ensure maintenance of the correction a triangular wedge of bone obtained from the iliac crest or the bone bank is fitted into the defect slight overcorrection is desirable the wound is closed in layers and the limb is immobilized in a plaster spica extending from the crest of the ilium to the toes

Postoperative Management After 6 or 8 weeks of plaster fixation usually sufficient healing has occurred at the osteotomy site to permit removal of the cast At this time a knock knee brace is applied to prevent recurrence of the deformity this is worn until roentgenographic studies reveal that bony union is adequate to preclude recurrence of the angular deformity this may be a period of 4 to 6 months Night splints are worn during the sleeping hours

SEVERE VALGUS DEFORMITIES

Severe valgus deformities subsequent to extensive crushing injuries to the lateral portion of the epiphyseal plate present more difficult problems When the injuries occur in young children, the subsequent angular deformity and shortening of the limb are invariably severe, producing pronounced dysfunction (Fig 233 A and B) Abbott and Gill pointed out that in these cases the goal of any operative procedure must be correction of the deformity and restriction of loss of length to a minimum After skeletal maturation is attained any residual inequality in length may be corrected by shortening the unaffected leg or lengthening the involved leg Correction of the deformity is achieved by an oblique osteotomy immediately above the affected condyle and opening a triangular wedge at the site of the deformity (Fig 233 C) This precludes the creation of a deformity in the opposite direction such as results when an osteotomy is performed at a higher level A triangular wedge of bone taken from the ilium is placed in the defect on the lateral side of the bone This procedure restores the anatomic relation of the lateral to the medial condyle and increases the functional length of the limb In the event that a varus deformity of the tibia is present correction of the femoral angular deformity may result in a bowing of the lower leg The varus deformity is also corrected by an oblique osteotomy on the medial side of the tibia at the site of the deformity by opening the wedge the bowing deformity is obliterated (Fig 233 D) This last procedure will provide additional functional length Correction of the tibial deformity is performed after union is complete at the site of the femoral osteotomy

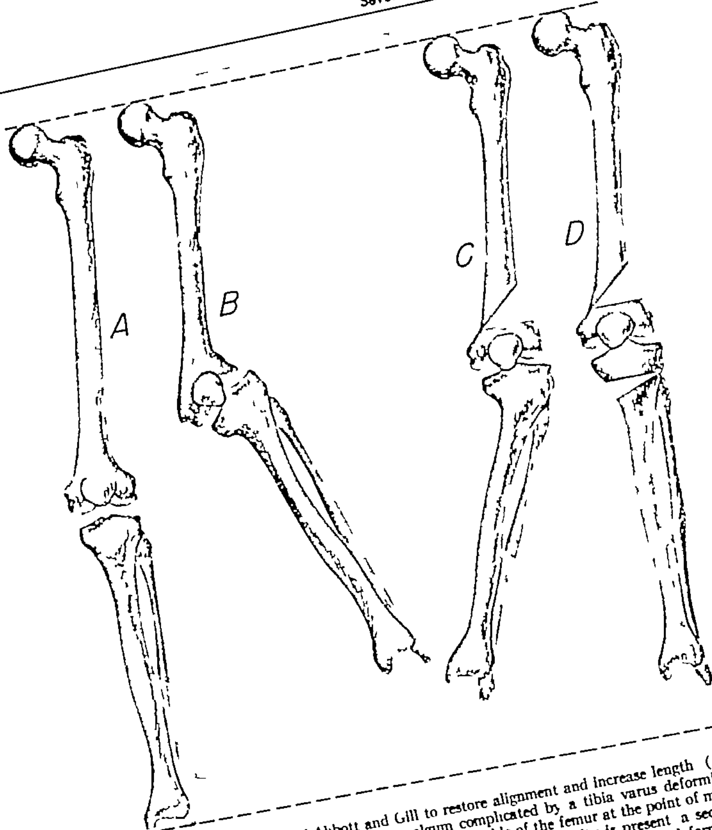


Fig 233 Technic of Abbott and Gill to restore alignment and increase length (A) The normal limb (B) Severe genu valgum complicated by a tibia varus deformity (C) An oblique osteotomy is done on the lateral side of the femur at the point of maximum deformity (D) In the event that a tibia varus deformity is present a second osteotomy is performed on the medial side of the tibia at the site of the deformity (Redrawn with modifications from Abbott and Gill)

Technic for Correction

Correction of severe valgus deformities by the aforementioned procedures may be hindered by the restraining influence of short contracted tissues on the lateral aspect of the thigh ... the knee the per

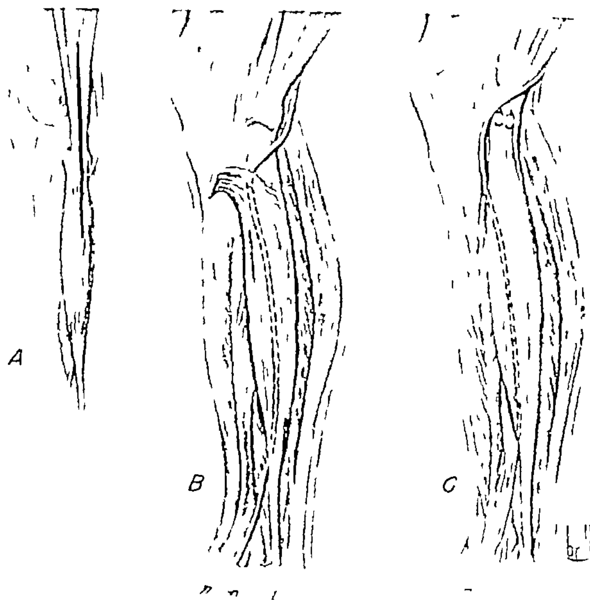


FIG 234 Transplantation of the peroneal nerve to an anterior position (A) Note that first the nerve is in relation to the outer margin of the biceps femoris then hooks around the head of the fibula to an anterior position (B) The nerve is uncovered by dividing the fibular origin of the peroneus longus and the overlying deep fascia. (C) The nerve is mobilized and transplanted to a more anterior position

oneal nerve is the most important single structure demanding special consideration The lateral region of the knee is exposed by a bony J incision beginning 2 or 3 inches above the lateral epicondyle and ending approximately 2 cm below the patella the deep fascia is divided in the line of the skin incision If the patella is displaced laterally it may be mobilized by dividing the lateral quadriceps expansion and dissecting it free from the lateral intermuscular septum The septum is divided transversely at the level of the epicondyle and dissected free from the lateral aspect of the femur as high as the level selected for the osteotomy The tendon of the biceps femoris is divided by a Z-cut and is lengthened later Occasionally it may be necessary to divide the iliotibial band transversely this last step may also be done as a prophylactic measure to prevent recurrence of the deformity *In addition* the lateral head of origin of the gastrocnemius muscle is dissected free from it

point of insertion into the posterior aspect of the lateral epicondyle

The peroneal nerve may be transposed to an anterior position, as described by Milch this may be performed as a prophylactic measure or in the presence of manifestations pointing to implication of the nerve. Palsy following correction of valgus deformities of the knee joint has been observed by many workers. Platt reminds us that severe traction of the peroneal nerve, associated with abduction injuries of the ligamentous structures on the lateral aspect of the knee, may result in peroneal palsy, "ligamentous-peroneal syndrome" Peroneal paralysis may be a complication of extensive treatment of fractures of the leg and leg lengthening is another complication when symptoms of this sequela are manifest, it is important that release of tension be executed immediately

The anatomic position of the peroneal nerve in relation to the structures on the lateral side of the thigh and the knee renders it vulnerable to traction and abduction mechanisms It pursues a downward cross behind the outer margin of the biceps femoris and crosses the lateral aspect of the head of the fibula to reach a more anterior position at the point of crossing the nerve hooks sharply around the head of the fibula and it is fixed in this position by the fibular origin of the peroneus longus and the deep fascia of the leg which insert into the fibula (Fig 234) Division of these structures permits transplantation of the nerve to an anterior position

By retracting the vastus anteriorly the bone is exposed by subperiosteal dissection and the soft tissues are displaced to either side by Bennett retractors An oblique osteotomy is performed at the site of the deformity and the lateral condyle is levered downward to the level of the medial condyle opening a wedge on the lateral side of the bone A triangular piece of iliac bone is placed in the defect and the fragments and the iliac graft are stabilized in the corrected position by a long screw or by a screw pin which is left protruding from the skin

Management in Growing Children. In growing children, Abbott and Gill note that the medial portion of the epiphyseal cartilage plate should be permitted uninterrupted growth. If this is allowed, it becomes apparent that recurrence of the deformity is inevitable, in such an event, the operation should be repeated as often as is deemed necessary during the growth period The osteotomy should be executed before the medial condyle overgrows the lateral by more than 1 in By such a plan the deformity never assumes extreme proportions, loss of length is maintained at a minimum, and severe contractures of the soft tissues on the outer aspect of the knee and the thigh do not occur If the expected final height of the patient is acceptable, the epiphyseal cartilage plate of the opposite extremity should be closed before the inequality of leg length exceeds 2 in

MAXIMUM CORRECTION OF DEFORMITY IN THE UPPER END OF THE TIBIA

Valgus deformities in which the site of deformity is in the upper end of the tibia must be corrected by an attack on the tibia and not by a supracondylar osteotomy In uncomplicated cases without implication of the upper tibial cartilage plate or epiphysis the deformity is corrected readily by resecting a wedge of bone from the upper end of the medial aspect of the tibia If any torsion of the tibia is present, it is also corrected at this time. In more severe cases especially in those with marked retardation or cessation of growth in the lateral portion of the epiphyseal cartilage of the tibia a more direct attachment is indicated (Fig 235) Correction of the angular deformity is achieved best by an open wedge osteotomy on the lateral side of the tibia at the site of maximum deformity and the leg is dis-

placed medially A triangular piece of bone obtained from the patient s ilium or the bone bank is placed in the defect Further stabilization of the fragments may be obtained by transfixing the fragments with a threaded wire or a crew pin As in the correction of severe valgus deformities resulting from injuries to the lateral portion of the femoral epiphyseal cartilage advanced contractures of the soft tissue structures may be present in angular deformities due to implication of the upper end of the tibia When present they are treated in the manner described previously in this section The fibular collateral ligament may be a significant obstacle to correction in these angular

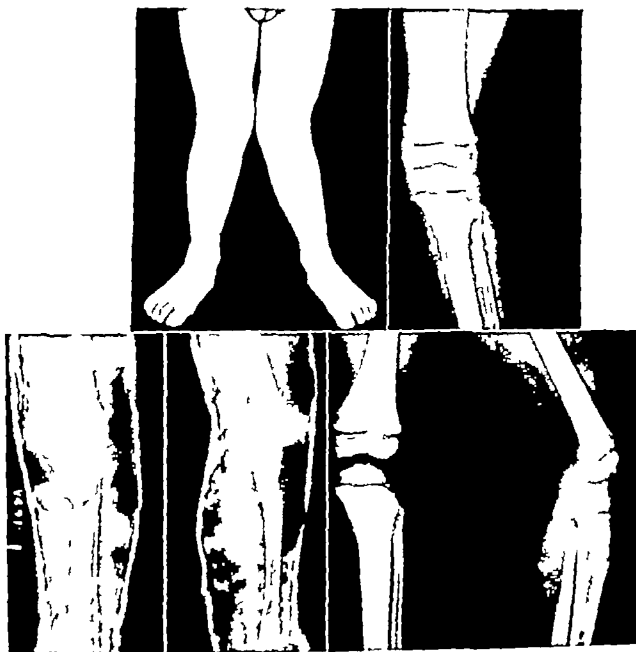


FIG 235 (*Top left*) Bilateral genu valgum in a child of 4 (*Top right*) Observe that the deformity is in the upper end of the left tibia. The roentgenograms clearly localize the lesion in the left extremity (*Bottom left*) Correction of the left leg was achieved by an open wedge osteotomy on the lateral a pect of the upper end of the tibia (*Bottom right*) Full correction still maintained 3 years later

deformities It may be necessary to free the structure from the head of the fibula, and after the desired correction is achieved it is attached to the lateral aspect of the tibial condyle

GENU VARUM (BOWLEG)

This deformity is characterized by a lateral displacement of the knee joint so that the joint lies to the outer side of the line of weight bearing dropped from the anterior superior spine of the ilium Generally, the deformity implicates the tibia or the femur the tibia and the fibula, the alterations in the bones of the lower leg are usually of greater severity than those observed in the femur In addition to an outward bowing the tibia also exhibits an internal twist or torsion from the knee to the ankle forcing the toes to turn inward When the child stands with the feet together, the medial borders of both extremities form an O the knees are widely separated

Etiology

Malacia bone diseases, especially rickets, predisposes the patient to development of this angular deformity when static factors are acting In the face of advanced softening of bones, the effect of body weight is sufficient to produce bending deformities and even stress fractures which may heal in malpositions (Fig 236) With the advent of vitamin D, the incidence of severe deformities associated with rickets has been reduced considerably Moreover the established custom of periodic examination of supposedly well babies both in private



Fig 236 (*Left*) Severe case of resistant rickets. Note the anterior bowing of both tibiae (*Right*) Roentgenograms reveal advanced osteoporosis and softening of the bones of both extremities. Observe the transverse fracture line in the left femur which is showing evidence of healing observe bending of both fibulae.



Fig 237 (*Left*) F W, 14 years old a case of ovarian agenesis. (*Center*) Roentgenograms reveal that there has been some interference in the normal growth of the medial portion of the upper tibial epiphyseal plates. (*Right*) Correction attained by open wedge osteotomies on the medial aspect of the upper ends of the tibiae Maximum correction on the left side has not been obtained.

practice and in institutions brings the ricketic child under care at a very early stage of the disease Hence, many severe deformities requiring surgical intervention are not encountered As a rule, children under the age of 4 years respond to non operative measures.

There is evidence that many cases of bow legs which are classified as congenital in origin are caused by the cross-legged position that the child assumed in utero Faulty postural habits may be causative factors favoring the development of bowlegs. Infants frequently sleep on the abdomen and face with the toes turned in and the knees widely separated Mild bowing in children under 4 years is observed frequently

Arrest of growth of the medial portion of the upper tibial epiphyseal plate is another cause producing the deformity The disturbance of growth may be the result of trauma or as in tibia vara a form of osteochondrosis Tibia vara is discussed subsequently in this chapter The deformity may be also observed in cases of enchondral ossification (dyschondroplasia) and in endocrine disturbances All these entities in some way interfere with the normal growth of the tibial and the femoral epiphyseal plates particularly medial portions or there may be cessation of growth of these portions of the plates Also these disorders may produce bowlegs by causing true bowing of one or both bones of the leg (Fig 237)

Clinical Features

As noted previously mild bowing in children under 4 years of age is a common observation When standing with the feet together the child's knees are widely separated and the inner aspects of the extremities form a symmetrical O When the child walks the gait exhibited is not unlike the waddle observed in bilateral dislocation of the hips In the presence of disorders such as malacic bone diseases dyschondroplasia endocrine disturbances and rickets the clinical manifestations peculiar to the condition are also manifested

Treatment

Generally mild forms of genu varum in young children under the age of 4 which are not associated with any bone metabolic

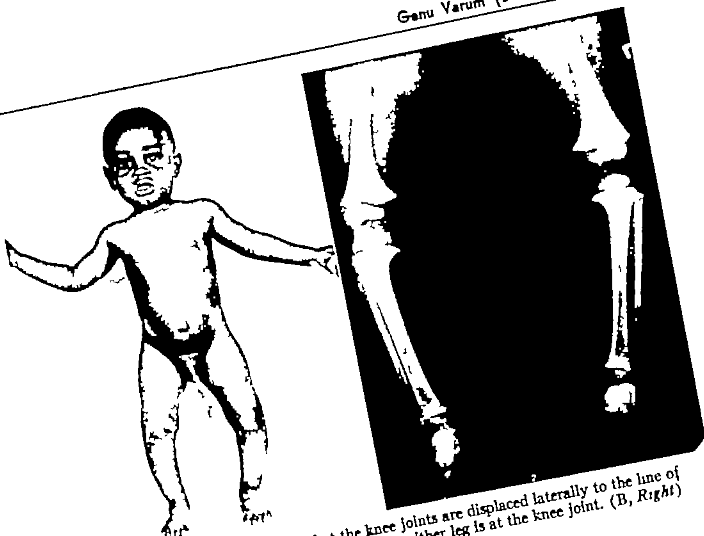


FIG 238 (A, *Left*) Observe that the knee joints are displaced laterally to the line of weight bearing The apex of the deformity in either leg is at the knee joint. (B, *Right*) These features are depicted clearly in the roentgenograms.

or endocrine disorders but are on a physiologic basis will be corrected with or without treatment In fact it is not uncommon to see a case of idiopathic bowlegs in early childhood become one of knock knees after the age of 4 Correction can be enhanced in these cases (before and after the age of 4 years) by inner wedges on the heel and the sole of the shoes and by manipulative maneuvers which tend to straighten the bowing Care should be taken not to perform forceful manipulations such measures may inflict damage to the epiphyses. Manipulations should be performed on a regulated schedule 10 or 15 times once or twice daily If these conservative measures fail to produce the desired results braces may be applied

Severe residual deformities of rickets in childhood and of latent rickets which is usually manifested about the age of puberty and severe deformities from other causes require surgical intervention to attain the desired alignment of the affected limb However, surgery is contraindicated in malacic bone diseases while the process is still active Correction of the deformity during this period is doomed to failure recurrence is the rule.

Surgical Correction of Bowlegs. Careful study of the configuration of the deformity is essential before surgical correction is attempted A tracing of teleoroentgenograms should be made first, then the bone of the leg at fault should be identified, and the site of maximum deformity localized By studying the problem at hand on a pattern the postoperative configuration of the extremity can be visualized, and the incidence of errors maintained at a minimum If the apex of the deformity is situated in the shaft of the femur or the tibia an open wedge osteotomy is preferred on the medial aspect of the bone to increase its length

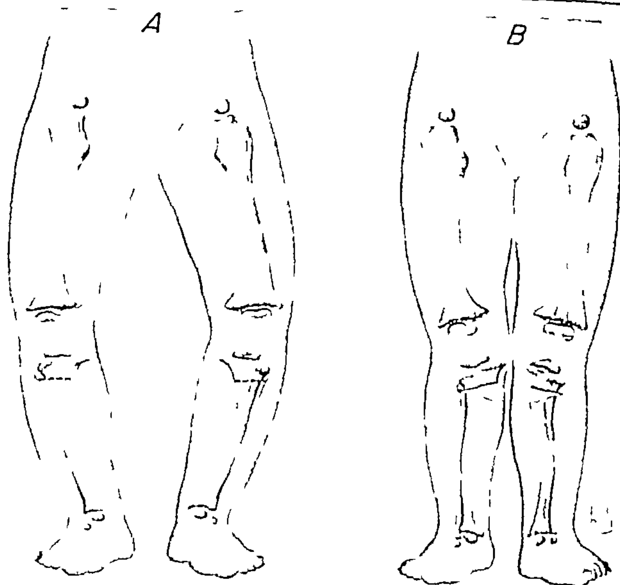


FIG 238 (*Continued*) (C) The pattern of the roentgenograms reveals that an osteotomy in the tibia restoring parallelism of its articular surfaces would convert the bowlegs (A) to knock knees (B)

TECHNIC FOR FEMUR. A longitudinal incision from 2 to 3 in in length is made on the inner aspect of the thigh centered over the proposed osteotomy site The bone is exposed subperiosteally and the soft tissues are protected with Bennett retractors With a thin sharp osteotome the bone is divided transversely three fourths of its diameter the remainder of the bone is fractured manually when the lower leg is abducted to the desired position A triangular piece of iliac bone is inserted into the defect Slight overcorrection of the bowing is desirable If further stability of the fragments at the osteotomy site is desired the fragments and the graft may be transfixed with a threaded wire or a pin which is cut below the level of the skin and withdrawn when the cast is removed

At the termination of the operation a plaster spica is applied extending from the costal cage to the toes on the affected side The cast is removed at the end of 6 weeks and the patient is fitted with bowleg braces

which are worn until bony union is complete, during the sleeping hours, night splints are worn

TECHNIC FOR TIBIA If the site of maximum bowing is in the tibia, an open wedge osteotomy is performed on the medial side of the bone at the apex of the bowing, and the converging planes of the articular surface of the tibia are restored to a parallel position The technic and the postoperative management are similar to those described for correction of the deformity in the femur When the osteotomy is performed in the shaft the fibula must be fractured also in order to achieve the desired correction

TECHNIC FOR APEX AT THE JOINT SPACE. When the apex of the deformity is at the level of the joint space, such as is observed in the O bowlegs Milch points out that an osteotomy above below or at both sites may convert bowlegs to knock knees. Study of the tracing of such a case depicted in Figure 238 illustrates this point In this child the apex of the varus deformity is at the joint space the knee joints are displaced laterally The tracings demonstrated clearly that an osteotomy above or below the level of the articulation converts the varus to a valgus deformity (Fig 238 C) In such cases better end results may be attained by the use of braces.

FIG 239 Infantile tibia vara This child, a female, aged 4, weighed 104 pounds. Observe the sharp angular deformity immediately below the proximal tibial epiphysis. The osseous portion of the epiphysis is wedge-shaped, with the base placed laterally the medial portion of the metaphysis is beak shaped.

TIBIA VARA

(*Osteochondrosis Deformans Tibiae*)

According to Blount this entity is not unlike other osteochondropathies such as coxa plana The observations of this observer are recorded in this section The lesion is more common than is generally realized and should be differentiated from other disorders capable of producing deformities of the knee Essentially it is a disturbance in growth which implicates the metaphysis the epiphyseal cartilage and the osseous center of the epiphysis The alterations are located on the medial side of the proximal tibial epiphysis and are responsible for an abrupt varus angular deformity just below the epiphysis In addition, varying degrees of genu recurvatum and internal rotation of the leg are constant concomitant abnormalities From a clinical viewpoint there are two types—infantile and adolescent

INFANTILE TYPE

This lesion is observed after the first or the second year of life in a child exhibiting

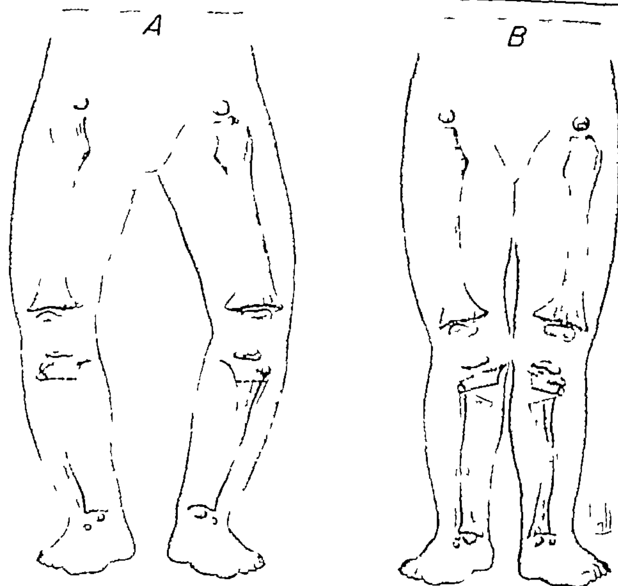


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INFANTILE TYPE

This lesion is observed after the first or the second year of life in a child exhibiting

normal development up to this time usually, overweight is an associated finding The child depicted in the roentgenogram in Figure 239 was 4 years of age the deformities were first noted by the parents at the age of 2 the child s weight was 104 pounds Usually most infants exhibit a mild physiologic bowing of the legs With growth this deformity is converted into a mild form of knock knees When tibia vara exists the *varus deformity becomes exaggerated with* increased growth In approximately 50 per cent of the cases it is a bilateral lesion No responsible etiologic factor has been identified rickets and other malacic bone disorders are not causative agents There is evidence suggesting that a congenital factor may play a role in the infantile type

Roentgenographic study points to a common cause The essential features are (1) a sharp angular deformity immediately below the proximal tibial epiphysis (2) the medial portion of the epiphyseal cartilage may *be expanded and irregular* (3) the osseous portion of the epiphysis is wedge shaped with the base placed laterally (4) the medial portion of the metaphysis is prominent, resembling a beak (5) irregular cartilage islands are observed in the beaklike projection of the metaphysis and (6) the prominent position of the metaphysis projecting medially, is covered by hyaline cartilage (Fig 239) These features eventually grade into those observed in the adolescent type

Pathology The pertinent features in the *infantile type are the abnormal growth of* the epiphyseal cartilage plate and retarded ossification of the medial portion of the tibial epiphysis The metaphysis throws out a beaklike projection which functions as a buttress under the epiphysis. Within this metaphyseal projection are irregular areas of cartilage which are depicted in the roentgenograms as areas of decreased density The microscopic appearance bears a close similarity to that observed in chondrodysplasia

Adolescent Type

This form is encountered between the



Fig 240 (A) Adolescent tibia vara Observe that except for the angular deformity immediately below the narrowed epiphyseal plate the bones appear to be normal The patient was a female aged 13 The deformity had existed 4 years prior to the taking of this roentgenogram.

ages of 6 and 12 years in children who were apparently normal in every respect up to the onset of the disorder The lesion is usually unilateral Although the etiologic agent is not known trauma may be the responsible factor in some, and in others some evidence suggests that chronic infection may play a role Regardless of the cause the roentgenographic features are governed by the age at which the lesion develops and not upon the modus operandi If roentgenograms are taken later in life it is impossible to determine whether the lesion was first manifest in the first or the second period of growth

Roentgenographic Features. Essentially, the findings suggest an arrest of



Fig 240 (B *Top*) Same case as A Severe varus deformity of the left extremity Correction was obtained by an open wedge osteotomy at the maximum site of the deformity (C, *Bottom*) Observe the restoration of normal alignment and the range of flexion and extension in the knee joint



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FIG 240 (B, *Top*) Same case as A Severe varus deformity of the left extremity Correction was obtained by an open wedge osteotomy at the maximum site of the deformity (C, *Bottom*) Observe the restoration of normal alignment and the range of flexion and extension in the knee joint.

growth of the medial portion of the proximal tibial epiphysis which results in the development of varus deformity immediately below the epiphyseal plate The epiphyseal plate shows some irregularity and may be more narrow on the medial side than on the lateral in fact in some cases the medial portion of the plate may be obliterated Below the metaphysis there is an abrupt angular deformity varying in severity with the apex laterally Except for the alterations noted in the region of the medial aspect of the upper end of the tibia the bones of the leg appear to be normal (Fig 240 A)

Clinical Features As noted previously the infantile type is bilateral in a large number of the cases whereas in the adolescent it is usually unilateral The onset is insidious in nature there is a gradual increased development of a varus deformity without clinical evidence of any local or systemic disorder In bilateral cases of the infantile type spontaneous correction may occur on one side Bilateral cases exhibit a waddling gait while a limp is present in the unilateral cases The knee and the foot on the affected side are subject to abnormal stress incident to function and hence may show evidence of strain

Inspection of the limb reveals a sharp angular deformity immediately below the knee and in all cases varying degrees of genu recurvatum internal rotation of the tibia on the femur and pronation of the foot are constant concomitant features In young children a prominent enlargement of the medial condyle is discernible Some shortening of the extremity (1 to 2 cm) is usually demonstrable The supportive structures on the medial side of the knee joint show increased laxity Occasionally the abnormal strain on the ligamentous structures produces pain and effusion in the knee joint

Treatment As in coxa plana and other osteochondroses spontaneous correction may occur this return to normalcy appears not to be governed by any conservative measure of treatment It is essential however to prevent undue strain on the knee joints and to correct existing pronation of the feet by braces and corrective shoes Such measures may suffice in the mild forms of the disorder and should be continued until there is clinical and roentgenographic evidence that the deformity is stationary At this time in adolescents and in adults if the degree of dysfunction or the disfigurement is not acceptable surgical intervention is justifiable Inasmuch as the deformity does not increase after the epiphyseal cartilage plate is closed in adolescent cases in which there is obvious damage of the plate it is advisable to postpone any operative correction until closure of the plate is achieved If the surgical correction is performed correctly no recurrence is a certainty The problem is more difficult in the infantile group with damage to the plate In some cases the lesion progresses for 3 or 4 years and then becomes stationary without becoming reactivated at a later period In others after a stationary period the deformity continues to increase in severity Occasionally the grade of the deformity makes surgical correction desirable even in the infantile group The correction should be performed in the stationary period if the process remains stationary no recurrence will ensue However if the process should become reactivated recurrence of the deformity may supervene

Technic The author s operation of choice is an open wedge osteotomy at the site of maximum deformity on the medial side of the leg The technic is similar to that described for the correction of genu varum when the angular deformity is primarily in the tibia In tibia vara the transverse osteotomy should be immediately below the epiphysis at the apex of the angulation This method not only corrects the angulation but regains some length of the tibia Any existing internal rotation of the tibia is also corrected The limb slightly over corrected is encased in a plaster spica from

the costal cage to the toes with the knee slightly flexed Immobilization is continued until there is roentgenographic evidence that bony healing is complete The subsequent treatment is similar to that recorded following operative correction of genu varum (Fig 240 B)

GENU RECURVATUM

This angular deformity resulting from trauma to the proximal tibial epiphysis is relatively uncommon when compared with the number of these deformities occurring subsequent to injuries to the distal femoral epiphysis However, operative procedures on the upper end of the tibia, such as curettage of a bony cyst or removal of a bone graft, occasionally may initiate sufficient disturbance of growth in the anterior half of the tibial epiphysis to produce a recurvatum deformity The lesion has been observed following advancement of the tibial tubercle in spastic children

Operative Correction

Essentially, the principles in the management of this lesion are the same as those recorded for the correction of other angular deformities It is important to restore the plane of the upper articular surface of the tibia to a position parallel with that of the lower Several technics have been designed to achieve this goal In all, the desired correction is attained by an osteotomy through the upper end of the tibia, however, the levels of the osteotomies differ

Brett s Procedure (Fig 241) A slightly curved skin incision is made in the anterior aspect of the knee joint, it begins on the inner aspect immediately above the tibial condyle then curves around the anterior surface of the tibia, crossing the patellar tendon slightly proximal to the tibial tubercle it ends over the outer aspect of the outer condyle The proximal flap of skin is dissected away from the patellar tendon and retracted upward, an incision is made on

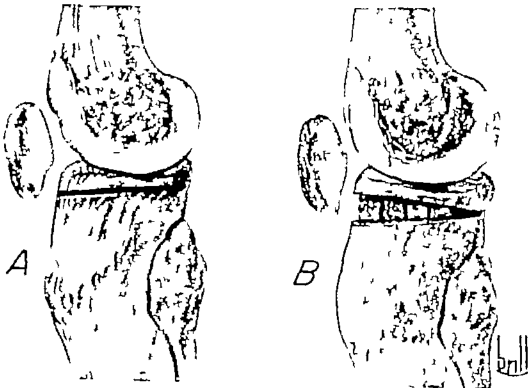


Fig 241 (A) Brett s osteotomy for correction of genu recurvatum (B) The proximal fragment is maintained in position by cortical bone structs placed in the triangular defect.

each side and parallel with the patellar tendon These incisions make accessible the entire anterior surface of the tibia including that portion behind the patellar tendon With a sharp thin osteotome the bone is divided transversely just below the attachment of the capsule into the margins of the tibia the posterior cortex is left intact By forcing the proximal segment upward a wedge-shaped space is opened on the anterior surface of the tibia Cortical bone struts are placed in the defect to maintain the corrected position (Fig 242) The wound is closed in the usual manner and the limb is immobilized in a plaster cast extending from the groin to the toes with the knee in extension

Postoperative Management The extremity is fixed in plaster for 6 to 8 weeks at the end of this period the cast is removed and physical measures are instituted to restore joint function Weight bearing is not allowed before the end of 12 weeks Braces or cages should not be employed rather, the quadriceps should be developed sufficiently to provide adequate stability and protection for the knee joint

Campbell's Procedure The upper end of the tibia is exposed by a 3 inch to 4 inch incision made parallel with the patellar tendon It ends approximately 1 in below the tibial tubercle The bone is exposed by subperiosteal dissection with a sharp thin osteotome the tibia is divided completely at the level immediately below the tibial tubercle By elevating the upper fragment a wedge-space based anteriorly is opened The amount of elevation of the anterior portion of the proximal fragment should be sufficient to correct the forward tilt of the artic



Fig 242 (A) Severe genu recurvatum of left knee following an old fracture of the upper end of the tibia The patient is a male 18 years old. (B) Roentgenogram taken

ular surface of the tibia. The desired position is maintained by two wedge-shaped bone grafts These may be obtained from the anterior surface of the same tibia at a lower level through a separate incision (The author prefers to use iliac grafts cut to the desired shape rather than cortical grafts taken from the tibia.) The grafts are fitted into slots previously cut on the anterior surface of the opposing osteotomized surfaces—one on the medial side and one on the lateral The remaining defect is packed with bone chips Before the wound is closed, roentgenograms should be taken to see whether or not the deformity is completely corrected

Postoperative Management After closure of the wound, a plaster cast is applied





Fig 242 (C, *Top*) Roentgenograms taken following correction by the Brett technic. Note elevation of the articular surface of the tibia. The cortical bone struts are still discernible 8 months postoperatively (D, *Bottom*) Position of the limb 26 months postoperatively No loss of correction has occurred

extending from the groin to the toes immobilizing the limb in 135 flexion at the knee joint the extremity is elevated in a balanced suspension apparatus and bags containing ice are placed around the cast at the level of the operative area This cast is removed at the end of 3 weeks and replaced by a similar cast fixing the limb in less flexion Ten to 12 weeks postoperatively *bony healing is usually sufficient to permit* removal of the cast and protected weight bearing on crutches At this time an intensive regulated regimen is instituted to restore joint motion and quadriceps power Nonprotected weight bearing is allowed when roentgenograms reveal good bony healing and when the quadriceps is sufficiently strong to stabilize the knee joint adequately

Irwin s Procedure (Fig 243) This method was designed originally for the correction of genu recurvatum following poliomyelitis however it can be utilized for correction of the deformity produced by other causes such as injuries to the proximal tibial epiphysis or fractures of t upper end of the tibia which have heal with some backward angulation of the fr ments producing forward tilt of the art ular surface of the tibia This method : sures control of the upper fragment skeletal traction until the desired correcti in all planes is attained Before the tibia osteotomized the lateral aspect of the sh: *of the fibula just below the neck is expos* through a 1 inch incision and then divid obliquely A segment of the shaft 1 in length is removed and broken up into sm: chips which are replaced in the defect T periosteum and the overlying soft tissu are closed in the usual manner

Through a second incision the upper e of the tibia is exposed subperiosteally a the bone is osteotomized in accordance wi the pattern shown in Figure 243 A A fi osteotome is used to cut out from the a terior cortex a tonguelike projection of bo attached to the lower fragment Before t bone is divided transversely a Kirschn wire is passed through the proximal fra

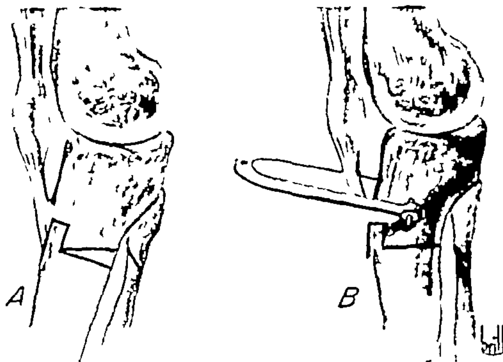


FIG 243 Irwin s method for correction of genu recurvatum (A) The pattern of the osteotomy in the tibia (B) correction is maintained by traction made on a Kirschner wire passing through the proximal fragment

ment, it traverses the bone at a right angle to the vertical axis of the knee joint. With a thin, broad osteotome the bone is osteotomized completely, and the upper end of the distal fragment is stripped from its periosteal attachments and displaced into the wound A wedge of bone based posteriorly, the size of which was calculated previously, is removed from the shaft of the distal fragment The anterior projection of bone is then fitted into the slot in the proximal fragment, and the two raw surfaces are opposed The wound is closed in layers At the end of the operation the patient is placed on a fracture table, and the limb is suspended to an overhead crossbar by means of a rope tied to a Kirschner bow attached to the wire in the proximal fragment (Fig 243 B) Hyperextension of the proximal fragment is achieved by the weight of the extremity while this position is maintained a plaster spica is applied from the costal cage to and including the wire the cast is allowed to harden fixing the pelvis, the femur and the proximal fragment of the tibia However the distal fragment is still free and can be manipulated in any plane in order to attain complete correction of the existing deformity This is accomplished with roentgenographic control next the cast is extended to the toes The wire is removed 6 weeks postoperatively the plaster spica is replaced by a long leg cast extending from the groin to the toes Eight to 10 weeks postoperatively the second cast is removed, the subsequent management is similar to that described for the postoperative management following the Campbell procedure

DEFORMITIES OF THE KNEE JOINT FOLLOWING POLIOMYELITIS

The most common deformities resulting from muscle imbalance produced by paralysis of muscles which motorize the knee joint are flexion contracture and genu recurvatum the former may be complicated by external rotation of the tibia on the femur and varying degrees of posterior subluxation of the tibia. Paralysis of the quadriceps may be complicated with a flexion deformity of the knee joint, this may occur when the hamstrings are not implicated or when they are partially affected In the event that the inner hamstrings are partially or completely paralyzed and the biceps femoris predominates in power, the flexion deformity may be further complicated by external rotation of the tibia on the femur, varying degrees of increased deviation at the knee joint, and stretching of the ligamentous apparatus on the inner side of the knee joint. In the early stages there is no alteration in the configuration of the articular surfaces in relation to each other, later, if the deformities remain uncorrected, the growing bone ends undergo structural changes, conforming to the existing alterations in the articulation

It was noted previously in this chapter that early and mild deformities respond to simple corrective measures, such as skin traction and turnbuckle or wedging-casts. More resistant deformities may need surgical intervention as posterior capsulotomy or posterior capsuloplasty, and if a valgus deformity persists after the flexion contracture is overcome supracondylar osteotomy may be required to complete the correction

The management of the paralyzed quadriceps muscle is considered in Chapter 13 'Surgical Approaches and Procedures' Yount observed that in cases of poliomyelitis the tensors of the fascia lata are the usual most important factors in producing flexion contracture of the hip these comprise the tensor fasciae femoris and a portion of the gluteus maximus whose tendinous portions blend with the fascia lata The fascia lata has a wide base of origin, extending from the coccyx posteriorly to ramus of the pubis anteriorly Between these two points it inserts into the sacrum the crest of the ilium and Poupart's ligament Its upper portion comprises two

layers which envelop the gluteus maximus and the tensor fasciae femoris. The iliotibial band is a thickened portion of the fascia along the lateral aspect of the thigh which converges distally. The band is continuous with the lateral intermuscular septum and contributes to the origin of the short head of the biceps femoris. As pointed out by Irwin, the iliotibial band lies in a plane lateral and anterior to the axis of the hip joint and in a plane lateral and posterior to axis of the knee joint. The fascia lata band inserts into the lateral aspect of the head of the tibia and the head of the fibula. When in a state of contracture, the tensors, in addition to producing a flexion and abduction contracture of the hip, also are responsible for lateral deviation and external rotation of the leg on the femur, producing a classical knock knee. In the presence of flexion deformities, the biceps femoris also plays a part in the production of the external rotation deformity of the leg. Based on this observation, Yount advocated division of the iliotibial band and the intermuscular septum above the level of the knee joint and, if necessary, lengthening of the tendon of the biceps femoris muscle in order to correct deformities of the hip and the knee. Occasionally, external torsion of the tibia may be a concomitant deformity of the aforementioned alterations. If the torsion is severe, it is corrected by an osteotomy of the tibia after the deformities of the hip and the knee are corrected. Failure to correct the deviation of the foot may predispose the patient to recurrence of the valgus deformity at the knee joint. The following surgical procedure was designed for cases with moderate deformities and of relatively short duration. In cases with severe and resistant flexion contractures of the hip, more radical surgery, as described by Irwin, may be necessary in addition to this procedure.

Yount's Procedure

The lower region of the lateral aspect of the thigh is exposed by a longitudinal incision from 3 to 4 inches in length. The iliotibial band is identified and divided transversely approximately 1 inch above the upper border of the patella, the cut extending anteriorly, dividing the fascia lata as far as the middle of the anterior surface of the thigh, and posteriorly to the biceps tendon. In addition, the lateral intermuscular septum, which lies between the vastus externus and the biceps femoris, is also divided. Some surgeons resect a segment of the iliotibial band and of the intermuscular septum (2 to 3 in.). Resistant and severe deformities may require lengthening of the tendon of the biceps femoris. As a rule, at the termination of the operation complete correction of the flexion deformity is not possible without force because of the existing contracture in the capsule and internal hamstrings. The remaining deformity is corrected slowly by wedging plaster casts. Wedging begins when soft tissue healing is complete, usually 3 weeks postoperatively. The wedging cast is cut circularly immediately below the level of the knee joint; during correction of the flexion deformity, the leg is forcibly rotated internally 2 or 3 times, and the amount of correction secured is maintained by the application of reinforcing plaster bandages.

Procedure for Flexion, Abduction and Rotation Deformities

The following procedure was designed for severe flexion, abduction and external rotation deformities of the knee without an associated flexion deformity of the hip. As a rule, in such cases a hip flexion contracture existed prior to the time that the patient becomes ambulatory on crutches. With ambulation, the weight of the extremity was sufficient to overcome the contracted structures about the hip. In these cases, however, the knock knee deformity tends to increase.

The structures on the lateral aspect of the knee are exposed by a curved incision beginning 1½ inches above the level of the joint over the biceps tendon. It curves anteriorly to the lateral border of the patella

and then continues downward and posteriorly, terminating just below the head of the fibula By retracting the skin flap posteriorly the sites of attachments of the fascia lata and the biceps below the knee joint are exposed With the knee in complete extension, all the contracted structures are readily discernible The biceps tendon is lengthened, and by subperiosteal dissection the iliotibial band and all ligamentous structures are stripped from the head of the tibia the stripping begins at the tibial tubercle and extends proximally to the superior margin of the tibial condyle The portion of the external lateral ligament attached to the head of the fibula is also released In addition, the lateral intermuscular septum is identified and detached by sharp dissection for several centimeters from the shaft of the femur When this last step is completed the knee is extended forcibly and rotated internally Postoperative management consists of slow correction of the remaining deformity by wedging casts as described previously

Irwin also emphasizes that numerous deformities of the lower extremity and the lower trunk may be produced by contractures of the fascia lata and the iliotibial band following poliomyelitis These may occur in the face of adequate conservative management. He lists the deformities as follows (1) flexion and abduction contracture of the hip (2) contracture of the thigh in external rotation (3) genu valgum, (4) short leg (5) knee flexion deformity, (6) external torsion of the tibia, with or without subluxation on the femur, (7) varus deformity of the foot following attempts to fit a brace on an extremity in which the tibia is rotated externally (8) external torsion of the femur, (9) pelvic obliquity and (10) exaggerated lumbar lordosis Correction of these deformities cannot be achieved by manipulative methods or by wedging casts In all instances regardless of the duration of the abnormalities or the age of the patient surgical methods are mandatory in order to obtain permanent correction When the hip is involved, division of the fascia lata according to the method described by Ober is an essential supplementary procedure to the Yount operation If postoperative correction is deemed necessary, this can be achieved by wedging in a double spica, as described by Irwin

Observations on Knee Flexion Deformities Following Poliomyelitis

The observations noted by Hughes in a study of knee flexion deformities following poliomyelitis are significant This investigation was made on 48 cases treated by open release of ligaments and muscles, 20 cases were treated by supracondylar osteotomy and 3 by tibial osteotomy The following conclusions were made

1 Rapid growth was the most important single factor responsible for recurrence of the deformity The final correction of flexion deformities attained in extremities not growing were better than those obtained in growing extremities

2 A good foot thrust was an important factor in producing complete extension or hyperextension at the knee joint. The foot thrust was most effective in the presence of a strong soleus muscle or an equinus deformity of the foot without axial rotation of the tibia

3 Good permanent correction by the aforementioned methods was achieved in the following order tibial osteotomy open release, supracondylar osteotomy and stretching

4 The degree of functional improvement achieved by these methods was in the following order open release, stretching supracondylar osteotomy and tibial osteotomy

5 In corresponding age groups open releases produced better anatomic correction than the other methods division of the posterior capsule fascia lata and iliotibial and lengthening of the biceps were most essential in obtaining these results.

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3 Good permanent correction by the aforementioned methods was achieved in the following order tibial osteotomy, open release, supracondylar osteotomy and stretching

4 The degree of functional improvement achieved by these methods was in the following order open release stretching, supracondylar osteotomy and tibial osteotomy

5 In corresponding age groups open releases produced better anatomic correction than the other methods division of the posterior capsule fascia lata and iliotibial and lengthening of the biceps were most essential in obtaining these results

6 *Following open release, in legs fully grown* 6 weeks of immobilization with the knee in 180° of extension sufficed to prevent recurrences, however, in growing limbs 12 weeks of immobilization with the knee hyperextended was necessary

7 The functional results in cases treated by open release surpassed those treated by other methods

8 Tibial osteotomy in recurvatum invariably *was followed by an increase in the* degree of recurvatum. The causes of apparent subluxation are recurvatum following tibial osteotomy and rotation of the tibia and the fibula. The anatomic and functional results *obtained by supracondylar osteotomy* were not as good as those obtained by open release, most of the knees showing a good anatomic result by supracondylar osteotomy had also been stretched thoroughly

9 Tibial subluxation in these cases was only apparent. It was uncommon in cases treated by supracondylar osteotomy and was observed frequently in those treated by open release, of which many also had tibial osteotomies in recurvatum. Stability of the joint was not impaired by the apparent subluxation. The three important factors governing the weight bearing function of the knee joint with a partially or completely paralyzed quadriceps and with some power in the hamstrings are recurvatum, gluteus maximus power and foot thrust

10 In cases treated by *supracondylar* osteotomy, the functional result was frequently vitiated by lateral relaxation and strain, this rarely occurred after stretching or open release

Genu Recurvatum Following Anterior Poliomyelitis

Comprehension of the mechanics responsible for genu recurvatum following poliomyelitis is essential in order to formulate a correct attack on the problem and to be able to prognosticate with some certainty the anticipated *result in the individual case. For* practical purposes the cases may be categoried into two groups (1) genu recurvatum with structural changes in the bony elements of the knee joint, *particularly* the tibia, and (2) genu recurvatum associated with advanced relaxation of the supporting soft tissue structures on the posterior aspect of the joint without alterations in the bony components. In each type the mechanism of production of the deformity differs and is the prime factor in determining whether or not osseous changes occur. Irwin analyzed the different mechanisms in the following manner

Genu Recurvatum with Osseous Alterations

The prime causative factor in this group is the inability (because of insufficient power) of the quadriceps apparatus to lock the knee in extension against resistance. A typical example would be one in which the hamstrings are not implicated, are not stretched and may even exhibit some shortening. In addition, the calf musculature also is not involved and usually is contracted and possesses more power than normal. Invariably the Achilles tendon becomes short, and the calf muscles overdevelop because of *the altered mechanics of the patient's gait*. When weight is borne on the affected extremity, first the heads of the metatarsals are brought in contact with the floor. This point of contact lies in a plane anterior to *that of the knee joint* and the interval between the heads of the metatarsal bones and the insertion of the Achilles tendon comprises the arm of lever through which the calf muscles exert their force, producing a resultant force which is directed backward against the posterior structures of the knee joint. This altered gait produces an exaggerated *spring in the step*, *the muscles on* the posterior aspect of the thigh and the muscles of the calf, both groups being normal, are resistant to stretching. In these cases the factors responsible for hyperextension are observed in the upper third and in the condyles of the tibia. In the normal

tibia the superior articular surface of the tibia forms an angle of approximately 90° to the shaft In the affected tibia the architectural pattern is so altered that the normal angle becomes more acute. In addition some posterior bowing of the upper third of the tibia is usually demonstrable and in some instances the tibia exhibits varying degrees of posterior subluxation The deformity evolves slowly over a relatively long period of time and conforms to Wolff's law "the changes in the static relations of bone lead to changes in structure and physiologic function"

Genu Recurvatum Without Osseous Alterations

The prime causative factor in this group is weakness in the calf musculature and in the hamstring muscles Rapid development of the deformity is the rule, without alterations in the bony components of the joint. Stretching of all the posterior supportive structures permits the joint to assume a position of hyperextension The structures involved are the posterior portion of the capsule, the posterior capsular ligaments and the hamstring muscles As a rule, a calcaneus or calcaneovalgus deformity of the foot on the same side is a concomitant finding When walking, these patients attempt to lock the knee in extension by an abnormal shift in the body weight, which creates a backward thrust on the posterior structures of the knee joint Continuous use of the limb in this fashion favors hyperextension of the limb by stretching the supportive soft tissue elements

Correction of Genu Recurvatum Incident to Anterior Poliomyelitis

Irwin points out that any form of surgical intervention designed to correct this deformity must fulfill two equally important requisites (1) restoration of the mechanical alignment of the extremity and (2) following restoration of the mechanical alignment, the responsible factors must be so

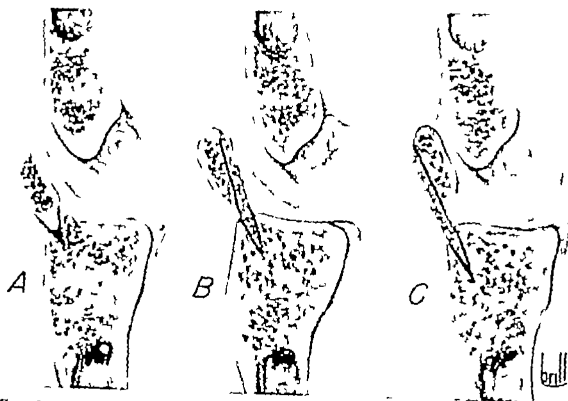


Fig 244 Types of anterior bone blocks designed to check hyperextension. (A) Campbell (B) Mayer (C) Milch.

altered that the recurrence of the deformity is precluded by the original mechanism Cases in the first group (showing alterations in the tibia with good power in the calf and the hamstring muscles) can be treated in such a fashion that the aforementioned requirements are fulfilled hence the prognosis is excellent This is achieved by restoring mechanical alignment by an *osteotomy of the upper third of the tibia* and later by transplantation of one or more of the hamstrings to the patella. By the latter procedure the patient is able to lock the knee in extension by the action of the transplanted muscles thereby eliminating the action of a powerful calf to stabilize the joint

In the second group (genu recurvatum without changes in the bony elements of the joint) the necessary requirements cannot be met hence the prognosis is poor No strong muscles on the flexor surface of the thigh exist therefore the quadriceps mechanism *cannot be reinforced by any type of muscle* transplantation It becomes apparent that the causative factors producing the deformity cannot be altered by surgical methods

As a rule these cases are forced to wear a *long leg brace to stabilize the joint* and to retain normal alignment of the extremity Operations on the soft tissues have been designed to check hyperextension of the joint on weight bearing Notably among these are the operations of Gill and Heyman However these methods in most instances have failed to achieve the desired results because the new check ligaments formed eventually stretch allowing recurrence of the deformity On the other hand Gill has reported some excellent long term results by this method Campbell and Mayer achieved correction of the hyperextension *deformity by creating an anterior bone block* the former fused the patella to the tibia while the latter utilized a free tibial graft to construct the anterior bone block (Fig 244) Of all the operations that described by *Irwin is the most simple and* effective It was designed for cases of genu recurvatum with alterations in the upper third of the tibia and with good power in the hamstrings and the calf muscles It comprises (1) an *osteotomy of the upper third* of the tibia performed to restore the mechanical alignment and (2) transplantation of one or two hamstrings into the patella. The second operation is performed after *bony healing is attained* it alters the causative factors responsible for the deformity Irwin s osteotomy is described on page 328 the technic for transplantation of the hamstrings is recorded in Chapter 13, "Surgical Approaches and Procedures'

Gill s Operation for Genu Recurvatum (Fig 245) This operation was designed for severe cases of genu recurvatum resulting from relaxation and stretching of the structures posterior to the knee joint Essentially it reconstructs a check ligament from periosteum and fascia lata with the purpose of preventing hyperextension

Technic *A longitudinal skin incision is* made on the lateral aspect of the thigh beginning from just below the head of the fibula and extending upward to the middle of the thigh A second incision is made on the inner aspect *it extends from the medial* condyle of the tibia to the junction of the middle and the lower thirds of the thigh the underlying fascia lata is divided in the line of the skin incisions and by blunt dissection the wounds are deepened to the femur On each side the periosteum is cut longitudinally so as to form a posterior one third and an anterior two thirds The posterior third is stripped by subperiosteal dissection from the femur from above downward until it becomes densely adherent to the bone and blends with the posterior and the lateral ligaments of the knee The ligaments are split longitudinally in line with the incisions through the fascia lata and the periosteum By means of a sharp thin osteotome the posterior periosteal flap together with the lateral ligaments is stripped from *the condyles of the femur* The stripping is

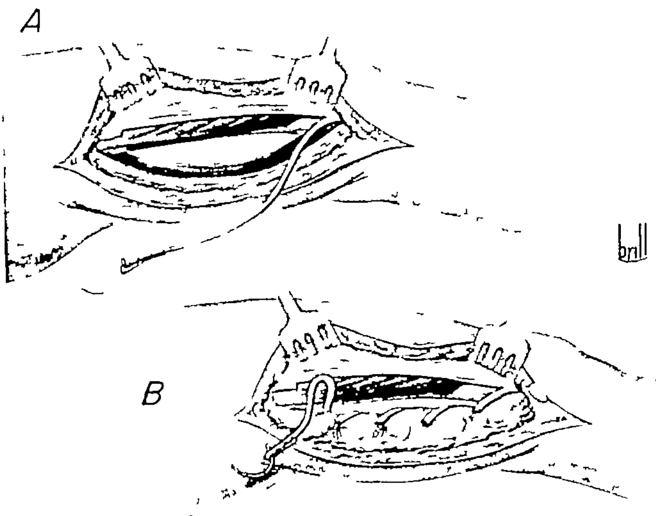


Fig 245 Gill s operation for correction of genu recurvatum. This method creates posteriorly a strong ligament-checking hyperextension.

continued distally under the lateral ligaments, separating them from the upper aspect of the tibia but leaving them attached to the tibia ½ inch below the level of the joint line In addition, the proximal attachment of the posterior ligament of the knee joint together with the periosteum, is separated from the femur A long strip of fascia lata is cut from the edge of the outer anterior fascial flap leaving its distal end attached this strip will be utilized as a suture (Fig 245 A) With the knee flexed, the posterior free edges of the periosteum and the posterior edges of the fascia on both sides are drawn together immediately behind the femur and approximated by the fascial strip which is used as a continuous suture (Fig 245 B) The suture should be continued as far down as possible because the farther it is carried distally the greater is the shortening of the newly constructed check ligament The procedure shortens all the structure on the posterior aspect of the femur and creates a stout check ligament to extension. The wounds are closed in the usual manner, at the termination of the operation the extremity is immobilized in a long leg plaster cast extending from the groin to the toes with the knee slightly flexed After 6 weeks, the limb is fitted with a brace which locks short of complete extension This protects the new ligament from any hyperextension strains, the brace is worn for approximately 3 months

FLAIL KNEE

Correct management of a paralytic knee is governed by the age and the occupation of the patient and the degree of involvement of the muscles motorizing the hip the ankle and the foot on the same side In general in the absence of muscles with good power about the knee *stabilization of the joint* is not possible by tendon transplantation The only other means of stabilization are a brace or arthrodesis of the joint There is no doubt that arthrodesis provides the *patient with a stable extremity improves* the patient s gait and eliminates a cumbersome brace On the other hand there are disadvantages, some of which are not acceptable to the patient In the sitting position the limb projects forward and creates an appreciable handicap If the patient s occupation is a sedentary one the disadvantages *of the sitting position with a stiff knee* becomes apparent. In occupations necessitating the standing position or walking it is to the patient s advantage to have a stiff knee in a good position of function and be free of the brace In growing children arthrodesis for a paralytic knee is rarely indicated arthrodesis performed before the epiphyseal *plates are closed may result in* disturbance of longitudinal growth or predispose the patient to a flexion deformity caused by a gradual epiphyseolysis at the distal end of the femur When fusion is deemed necessary it should be delayed until the fourteenth year In adults the decision should be made by the patient after all the advantages *and the disadvantages have been* considered In cases with extensive involvement of both lower extremities marked improvement in stability and ambulation can be attained by fusing one knee joint and *wearing a brace on the other extremity*

As recorded previously the flail knee may also exhibit other deformities such as flexion abduction and *external rotation of the lower leg* When these are mild in nature fusion may be performed without preliminary correction In more severe forms it is essential to restore alignment of the limb before fusion *is attempted This usually* entails a surgical attack on the posterior structures of the knee joint (capsulotomy or capsuloplasty) and division of the contracted fascia lata These preliminary procedures minimize the extent of shortening following the arthrodesis by permitting correction with minimal resection of bone *Stabilization of both the foot and the ankle* by arthrodesing procedure must not be performed in the presence of a stiff knee this combination results in a very labored form of ambulation the rocker" gait The indications and the contraindications and the different technics of arthrodesis are discussed in Chapter 13 Surgical Approaches and Procedures

TORSION OF THE TIBIA AND THE FEMUR

Tibial or femoral torsion is a twisting of the involved bone on its longitudinal axis in so doing the alignment of the planes of motion at the proximal and the distal articulations *are altered This is especially true* of the tibia Two types of rotational deformities are possible internal and external In the normal adult tibia approximately 20° of external rotation are demonstrable This is determined readily by the method described by Hutter and Scott The joints of the knee and the ankle for practical purposes *function as hinge joints the position* in which the planes are parallel is selected as the base position for measuring torsional abnormalities *Internal torsion occurs when* the rotation is in the direction of the internal malleolus, and external torsion when it occurs in the direction of the external malleolus A line parallel with the proximal *articular surface* of the tibia is projected through the coronal plane of the tibia a second line passes through the center of the malleoli *at the point of coincidence these* lines establish the angle of torsion (Fig 246 A and B) The average tibial torsion in

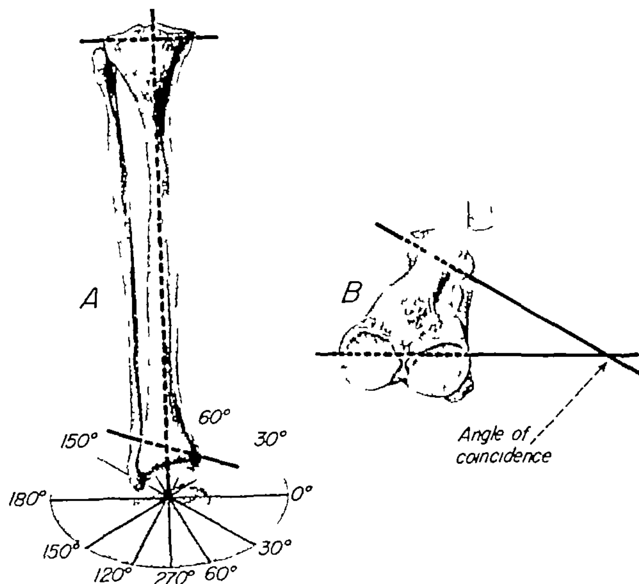


FIG 246 (A and B) Method of determining tibial torsion One line passes through the coronal plane of the tibia parallel with its proximal articular surface, a second line passes through the center of the malleoli. At the angle of coincidence these lines establish the angle of torsion. (Redrawn from Hutter and Scott)

the normal adult is 20° a variation of 20° is within normal limits. By this criteria an angle beyond 40° in external rotation and beyond the neutral or base position in internal rotation must be considered unphysiologic and of clinical importance

Rotation deformities of the tibia and the femur are produced by numerous and divergent causes Not infrequently they are observed subsequent to anterior poliomyelitis producing muscle imbalance in the lower extremities The lesions may be evidence of growth disturbances in static or congenital abnormalities of the bones and the joints or may be caused by malacic bone diseases endocrine disturbances or infectious processes It has been pointed out previously that external rotation of the tibia may be a concomitant structural alteration of valgus and flexion deformities of the knee also not infrequently internal torsion of the tibia or the femur is observed in varus deformities of the knee and dislocations of the hip

The most common cause of tibial and femoral torsion is some extrinsic mechani

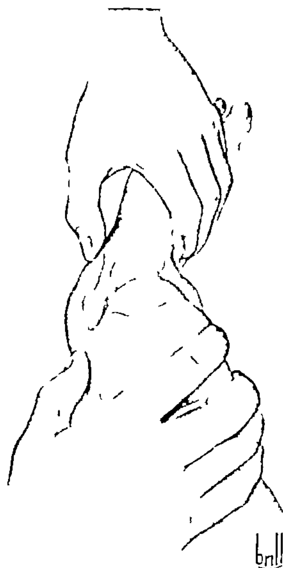


Fig 246 (*Continued*) (C) Method of examination for tibial torsion.

cal factor acting during the developmental stage or shortly after birth resulting in either an internal or an external deformity of the bones The tibia is implicated most frequently Also there is evidence suggesting that abnormal stresses imposed on the extremities in infancy and early childhood produce internal or external rotation deformities of the tibia Depending on the direction of the rotary stress applied many children with internal torsion of the tibia develop the habit of sleeping upon the abdomen with the hips and the knees flexed and the feet turned inward On the other hand many children with external rotation deformities acquire the habit of sitting on their legs with the knees flexed and the feet widely separated and rotated externally In the latter group varying degrees of abnormal anteversion of the femoral neck is observed in the cases showing marked external rotation of the femur Hutter and Scott observed that in Orientals who are accustomed to sitting on the floor with their legs folded under them and their feet pointing inward immediately beneath the buttocks internal torsion deformities of the tibia is a constant finding and is produced by the superincumbent weight of the body forcing the tibia into the position of internal rotation It is interesting to note that descendants of Orientals who have adopted the mannerisms of the Western civilization fail to show a higher incidence or torsional deformities of the tibia than is found in the American population

The aforementioned workers noted further that infants and preschool children have less external rotation than adults that normal developmental alterations particularly in school age children fail to correct to any extent severe torsional deformities of the tibia and that relatively little correction of internal torsion deformities of the tibiae occurs after the age of 7 years this degree of deformity will most likely be present when the child becomes an adult

For clinical purposes the degree of torsion can be estimated by physical examination by noting the relations of the patella to the malleoli The patient sits in front of the examiner with the knees flexed 90 and with the patellae pointing directly forward The left hand of the examiner is placed under the popliteal space and gently supports the leg so that the foot is not making firm pressure against the floor The thumb and the index finger of the right hand grasp the malleoli By looking down the longitudinal axis of the tibia the angle of torsion is established by calculating the angle made by a line passing through the bicondylar axis of the tibia and a line passing through the

center of both malleoli Another method of detecting the presence of torsion is by extending the leg with the patella pointing straight upward, the thumb and the index finger of one hand grasp the ends of the bicondylar axis of the femur, and the thumb and the index finger of the other hand are placed over the internal and the external malleoli, the angle formed by these lines passing through the bicondylar and the bimalleolar axes is the angle of torsion (Fig 246 C)

Treatment

The author has found manipulative measures in combination with the use of night splints forcing the legs in the opposite direction to the existing torsional deformities to be a very effective method of treatment. When in addition to the internal torsional deformity the child exhibits an outbowing of the entire tibia both deformities must be corrected

Manipulative Technic. For internal torsion deformities the child lies on the back and the mother takes her position at the child's feet. One hand is placed over the anterior surface of the knee and grasps firmly the upper end of the tibia, and the other hand grasps the ankle She firmly and steadily derotates or untwists the leg by forcing the foot outward this position is maintained for 10 to 20 seconds, and then the limb is released The maneuver is repeated from 8 to 10 times twice daily To correct the lateral bowing of the leg the mother stands at the side of the child and grasps the knee and the ankle with one hand above and one below the palmar surfaces of the thumbs are placed along the lateral aspect of the child s leg Inward pressure is then exerted by the thumbs over the middle of the leg As above, the correction position is maintained for 10 to 20 seconds and then released The maneuver is executed 8 or 10 times twice daily For external rotation deformities the above procedures are reversed

During the sleeping hours the child wears a Dennis Browne splint with shoes attached to the foot plates holding the feet in the desired position of internal or external rotation. At first the plates are so adjusted that in cases of internal torsion the feet are held in 20° of external rotation, this is increased gradually, in severe cases the feet may be forced outward as much as 40° to 45° In order to prevent development of knock knee deformities the length of the bar must not exceed 8 inches With the above regimen correction of uncomplicated deformities is usually achieved in from 4 to 6 months In cases of tibial torsion Hutter and Scott advocate discontinuance of the splint before full correction is attained in order to allow for compensatory alterations in the architectural pattern of the limbs in the subsequent growth period

Surgical Correction in Tibial Deformities. Severe torsional deformities in children which fail to respond to conservative measures and those encountered in adults require surgical intervention Essentially, this comprises derotation osteotomies of the tibia and the fibula. A distinction must be made between torsion deformities existing as uncomplicated lesions and those which are associated with angular deformities of the knee joint, such as valgus and varus deformities

In children correction may be attained readily by a torsional osteotomy without losing continuity of the fragments This method is also applicable to cases of resistant clubfeet with internal torsion of the tibia. Often correction of the varus and the equinus deformity of the foot cannot be attained until the internal torsion element of the deformity is overcome

Rotational Osteotomy Kirschner wires are passed through the upper and the lower ends of the tibia, the proximal wire traverses the bone parallel with the center of the articular surfaces of the tibia while the distal wire is placed parallel with the bimalleolar axis Midway between the two points a skin incision 2 to 3 inches in length

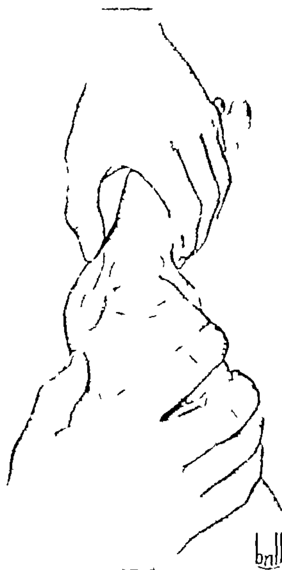


FIG. 246 (*Continued*) (C) Method of examination for tibial torsion

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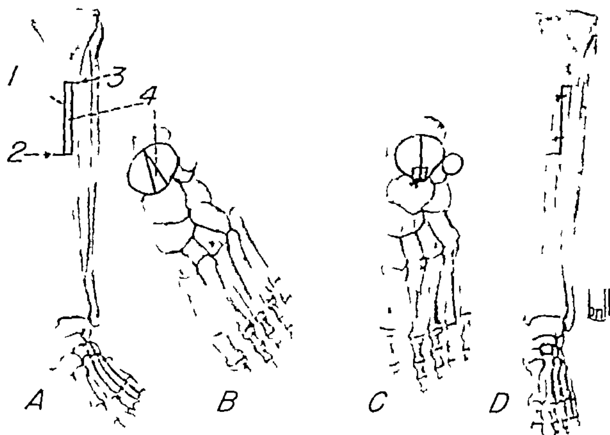


FIG 247 O Donoghue s rotation osteotomy of the tibia. (A) The distal horizontal transverse cut of the Z is always on the side of the correction. (B) Depicts the segments of bone removed between the two longitudinal cuts in the tibia (C and D) The deformity is corrected by rotating the leg inward, and the fragments are fixed by sutures passing through drill holes in both fragments (Redrawn from O Donoghue)

is made over the anteromedial aspect of the tibia The bone is exposed subperiosteally and the soft tissues are protected by Bennett retractors. Five or six linear cuts are made with a motor saw around the circumference of the bone the desired correction is attained by twisting the leg distal to the osteotomy site in the opposite direction to the existing deformity The periosteum and the skin are closed in the usual manner At the termination of the operation the Kirschner wires are used as guides the leg is twisted until the correct relationship is restored between the upper and the lower articular surfaces of the tibia While this position is maintained by the surgeon an assistant applies a circular cast incorporating the wires the cast extends from the groin to the toes

Postoperative Management At the end of 6 to 8 weeks bony healing is usually sufficient to permit removal of the pins and the cast and to start protected weight bearing

ROTATION OSTEOTOMY OF THE TIBIA (O'DONOGHUE) (Fig 247) This procedure allows excellent control of the fragments and ensures bony healing by bringing into contact large surface areas of raw bone It should not be used in the presence of compound deformities because this method was not designed to correct angular deformities

Technic A skin incision 4 to 5 inches long is made on the anterior surface of the tibia

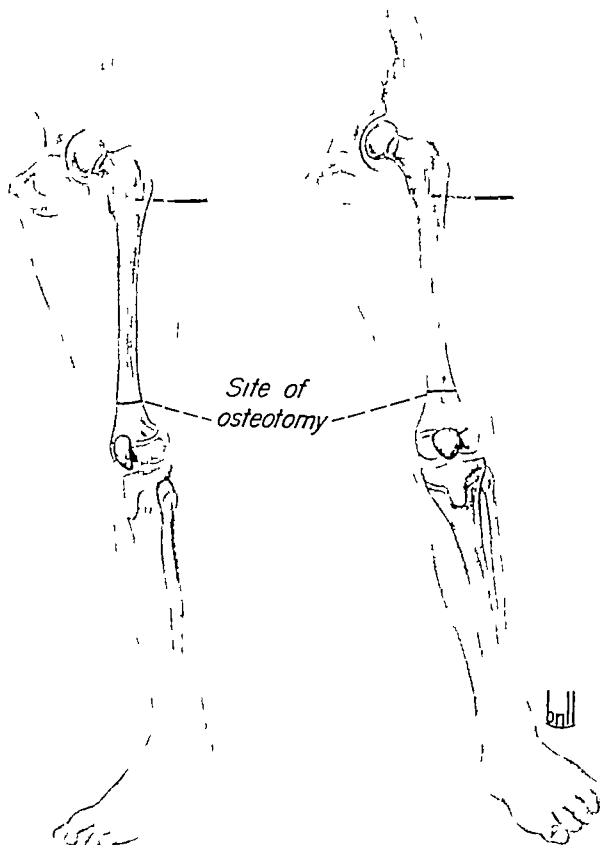


Fig 248 Derotation osteotomy for torsion of the femur The Steinmann pin in the greater trochanter is incorporated into the plaster spica This stabilizes the proximal fragment.

beginning slightly below the tibial tubercle and extending vertically downward The entire circumference of the tibia is exposed subperiosteally and the soft tissues are protected with Bennett retractors. A longitudinal cut 1½ to 3 inches in length is made with a motor saw in the anterior cortex of the bone. The cut is made parallel with the tibial crest and 1 to 1½ inches medial to it Two transverse cuts are made at the ends of the linear cut converting the line of osteotomy into the shape of a Z the distal horizontal transverse cut of the Z is always on the side of the direction of the correction For example if the leg distal to the side of the osteotomy is to be rotated inwardly the distal transverse cut extends from the longitudinal cut to the medial border On the other hand if the lower segment of the leg is to be rotated outwardly the distal transverse cut extends outward and the proximal cut inward A second longitudinal cut is made in the bone parallel with the first and on its outer side the width of the strip of bone between the two cuts depends upon the amount of correction desired The osteotomy is completed by removing the strip of bone and dividing the posterior cortex with a fine sharp osteotome Care must be taken not to injure the soft tissues on the posterior aspect of the leg By twisting the leg and closing the anterior edges of the osteotomy the rotational correction is achieved The corrected position is maintained by drilling holes through the two bony segments and tying them together with catgut sutures or fixing them with screws After closure of the periosteum and the skin the limb is immobilized in a plaster cast extending from the groin to the toes fixing the knee in 10° to 15° of flexion

Postoperative Management Plaster immobilization is maintained for 6 to 8 weeks After this period of time bony healing has progressed sufficiently usually to permit removal of the cast and to allow protected weight bearing

SURGICAL CORRECTION IN FEMUR DEFORMITIES

Surgical correction is achieved most readily by a supracondylar osteotomy, in children the line of division in the bone must be proximal to the epiphyseal cartilage plate in order to avoid injury to this structure The position of the proximal segment is controlled by a Steinmann pin driven into the greater trochanter and incorporated in the plaster cast

Derotation Osteotomy (Fig 248)

The extremity is rotated internally so that the greater trochanter assumes an anterior position through a stab wound in the skin a Steinmann pin is driven deeply into the base of the trochanter, its outer end is allowed to project from the skin

A vertical skin incision 3 to 4 inches in length is made over the lateral aspect of the lower third of the thigh The skin flaps are retracted and the fascia lata is divided in the line of the skin incision A line of cleavage is developed anterior to the lateral intermuscular septum until the shaft of the bone is reached The periosteum is divided longitudinally and stripped from the entire circumference of the bone Bennett retractors are placed above and below the shaft of the femur in order to expose adequately the osteotomy site and to protect the soft tissues With a fine sharp osteotome the bone is divided transversely just proximal to the metaphysis Then the distal segment and the lower leg are rotated in the opposite direction of the existing deformity—internally for external torsion and externally for internal torsion of the femur After derotation of the lower segment the patella should point straight forward The periosteum and the skin are closed in the usual manner A plaster spica from the costal cage to the toes is applied incorporating the Steinmann pin which holds the proximal segment in the corrected position

Postoperative Management. At the end

of 4 to 6 weeks the pin is removed, the cast is removed at the end of 8 to 10 weeks, depending on the extent of bony consolidation at the osteotomy site shown by roentgenographic examination A caliper brace should be worn for 6 to 8 weeks to prevent recurrence of the deformity or the development of angular deformities at the site of the osteotomy

DEFORMITIES OF THE KNEE INCIDENT TO CEREBRAL PALSY

The revived interest in cases of cerebral palsy has borne fruit, and there are indications that more valuable information is forthcoming Phelps, Carlson, Fay, Crothers and many other workers have made outstanding contributions Comprehension, at least in part, of the basic pathology and some understanding of the mechanisms of the intricate neuromuscular disorders in cases of cerebral palsy have been responsible for the present-day methods of treatment which are less pessimistic than they were several decades ago Surgical procedures performed in properly selected cases *must be considered as only a part of the* total process of rehabilitation whose prime consideration is to make the patient physically independent and acceptable to society Physical rehabilitative methods produce the best results surgery must be considered as an adjunct to these measures by removing barriers to and facilitating the broad plan of therapy

Essentially cerebral palsy is an impairment of the normal muscular mechanism resulting from lesions situated in the cortex the basal ganglia or the cerebellum The location of the intracranial lesion governs the type of peripheral neuromuscular dysfunction Clinically, the cases may be grouped into five categories (1) spastic (2) athetoid (3) ataxic, (4) rigidities and (5) tremor In addition mixed types also occur

Etiology

Cerebral palsy may be the result of numerous and unrelated causative factors Hitherto, birth trauma was considered as the prime etiologic agent responsible for the greater majority of these cases According to Phelps, only a small percentage (3%) are caused by injury at the time of birth. These injuries may be mechanical in origin, such as cortical hemorrhages or fractures of the skull produced by obstetric forceps or anoxia resulting from the deleterious effects of anesthetics, by an umbilical cord wrapped tightly around the infant's neck or by delayed resuscitation of the infant. It has been pointed out that a sudden change from the high intra-uterine pressure to atmospheric pressure may be a factor in causing rupture of the thin friable, cerebral vessels in infants born prematurely These mechanisms usually are responsible for the spastic type of cerebral palsy

Prenatal developmental or congenital defects of the brain are responsible for a certain number of cases the peripheral neuromuscular dysfunction in these cases is characteristic of the ataxic and the athetoid types Postnatal causes of cerebral palsy include such lesions as thrombosis, embolism and infectious diseases which may give rise to an encephalitis as pertussis, measles and pneumonia

Types of Cerebral Palsy

Spastic Type

In this type the cerebral cortex is implicated primarily As noted previously, most frequently it is the result of intracranial trauma. Characteristic of this type is the involvement of groups of muscles, rather than a single muscle and, depending on the location of the lesion in the cortex, the muscles may exhibit spasticity, flaccidity or both. The true spastic muscle elicits hyperirritability and hypercontractability on stretching This phenomenon, designated

the stretch reflex is readily discernible in a spastic quadriceps muscle Attempts on the part of the hamstrings to flex the knee initiate a powerful contraction of the quadriceps, blocking flexion of the knee Also, a spastic muscle may overpower and stretch its antagonists to the point that they become weak and ineffective This mechanism *is the basis of muscle imbalance about* joints, resulting in the formation of fixed deformities of the involved joints The deep reflexes are exaggerated the superficial reflexes are diminished and in some instances ankle clonus is demonstrable Only in rare instances is the lesion isolated to that portion of the cerebral cortex producing complete flaccidity of the affected limb If only one extremity is implicated the lesion is designated monoplegia hemaplegia indi*cates involvement of one side of the body* paraplegia applies to involvement of both lower extremities diplegia designates implication of either both lower or both upper extremities and quadraplegia implicates all four extremities. Approximately 40 per cent of all cases of cerebral palsy are of the spastic type

ATHETOID TYPE

In this group the abnormality resides in *the basal ganglia which normally possess* the faculty of selecting impulses from cortical levels This intricate mechanism is impaired and involuntary impulses are released giving rise to *bizarre unpredictable* un-co-ordinated involuntary movements The types of movements vary greatly they may be constant or intermittent slow or rapid or they may be manifest only with effort The muscles supplied by the cranial nerves as well as any or all of the extremities may exhibit these abnormal manifestations Implication of the muscles of facial expression and the muscles of speech are responsible for the characteristic grimacing and constant *twitching of the athetoids* often these features have been interpreted erroneously as evidences of mental deficiency In uncomplicated cases of this group (in which the cortex is not damaged seriously) the mentality may not be affected seriously Cases in this group are further classified as tension nontension tremor flail and dystonic The spasticity is more apparent than real however some muscles may exhibit increased tone or tension which *is an expression on the part of the athetoids* to bring under control the involuntary motions. The reflexes usually are not increased there is no ankle clonus and the Babinski test is negative the stretch reflex is also absent Tension in the athetoid will disappear if repeated passive flexion and extension movements are executed rapidly This type of cerebral palsy comprises approximately 30 per cent of the cases

ATAXIC TYPE

The predominant lesions involve the cerebellum although other portions of the brain may be affected Most cases are of congenital origin but in a small number hemorrhage sustained at birth may be the causative factor The characteristic clinical features are ataxis and impairment or loss of kinesthetic sense Ataxia is manifest by loss of balance and postural sense As a rule there are varying degrees of speech defects and in addition dizziness and nausea may be present In contrast with the spastic type the muscles of the ataxic exhibit lack of tone and diminished deep reflexes the ten*dons and the capsular tissues may be hyper*mobile Children in this group show evidence of greater spontaneous improvement than those in the other groups voluntary balance control may be achieved through re-education of the motor pathways

TREMOR AND RIGIDITY TYPES

Less is known in regard to the rigidities and the tremors than the other types of cerebral palsy They are rarely of congenital *origin* Tremor most frequently is an unfortunate sequel of postnatal encephalitis while rigidity may be the ultimate result of

prolonged postnatal anoxia, producing wide spread brain damage. A high degree of feeblemindedness is characteristic of these types, particularly in the constant rigidities In the rigidities loss of muscle elasticity is a predominant feature. When stretched, the muscles offer considerable resistance As a rule, the muscles disclose no hyperactivity, and the stretch reflex is absent. Two types of rigidities are recognized clinically the intermittent and constant. In the former periods of muscular relaxation occur, alter nating with periods of rigidity

PROGNOSIS

In cerebral palsies the many obstructions encountered to the progress of the patient render the outlook for complete rehabilita tion relatively poor The tendency to emotional instability impairment of speech development and intellectual retardation all are factors which preclude rapid advancement toward the desired aims of any com prehensive plan of therapy As noted previously, in many instances intellectual retardation is not the result of poor mental ity but rather of retarded development be cause these patients are unable to compete in the environment of normal children It becomes apparent that correct evaluation of the child s mental capabilities is the prime requisite before any plan of treatment is formulated Even in children with mental acumen progress is slow nevertheless it is gratifying to note the effort that some of these patients expend in trying to overcome their physical handicaps. The ultimate re sult is dependent upon the potentialities of the patient and the execution of a regulated preconceived plan of physical and mental rehabilitation

TREATMENT

It is not within the scope of this book to deal with the treatment of the different types of cerebral palsies However, some mention should be made of the methods em ployed in a broad plan of treatment. Cor rect evaluation of each individual case is essential, this demands the combined stud ies of pediatrician, neurologist, psychiatrist, psychologist and orthopedic surgeon Treat ment embodies the efforts of trained phys ical therapists, occupational therapists and speech therapists In addition, full co-opera tion of the parents is an essential part of the plan The role of the orthopedic surgeon is to remove obstructions to the physical rehabilitative program by improving pre hensional function and locomotion by se lected surgical procedures The over all plan is complex and spans many years of con certed effort

In the spastic group, treatment is directed toward the prevention of contractures and the acquisition of fundamental motions by constant repetition Because passive motions initiate the stretch reflex they should be avoided as much as possible In addition, the weakened and stretched antagonists should be strengthened Braces are useful adjuncts to permit the patient to assume the upright position and to control voluntary motions and to develop a sense of balance Also, braces are utilized to correct and pre vent contracture The spastic type is most amenable to surgical procedures, provided that the patients are selected carefully The operative procedures found most useful are neurectomies transposition of tendons lengthening of shortened tendons and ar throdeses

The athetoid cases present even more dif ficult problems Before voluntary motions can be taught, it is imperative to eliminate involuntary movements which interfere with the rhythmical performance of a single voluntary motion This can be achieved only by training the patient to attain com plete relaxation After this obstruction is overcome voluntary co-ordinated motions can begin Except for postural contractures of joints, the athetoid is not likely to de velop contractures When they occur braces may be employed to advantage braces may also be used especially on the lower ex

tremities to control involuntary motions

The aims in the treatment of the ataxic group are to improve muscle tone develop a sense of balance and to teach the patient to sit stand and walk As in the previous two types braces are useful valuable adjuncts to the treatment Surgery in these cases has nothing to offer and therefore is contraindicated

The methods of physical rehabilitation employed in the spastic and the athetoid groups are of little value in tremors and rigidities In these cases the intracranial damage is usually extensive Except for release of severe contractures in the rigidities surgery is not justified Medicinal therapy plays the major role in the management of these cases

SURGERY

Except in rare instances the spastic form of cerebral palsy is the only type which is amenable to surgical procedures provided that certain criteria are fulfilled According to Green and McDermott the following basic criteria must be established before surgery is considered

1 The patient must be thoroughly evaluated and the type of paralysis and the degree of motor dysfunction must be classified as correctly as possible

2 The patient s sense of balance should be established in order to determine whether or not it is sufficient to permit the anticipated result Patients unable to maintain a sitting position because of lack of sense of balance certainly cannot be expected to walk regardless of the type of operations performed on the lower extremities

3 The mental status of the patient must be established Gross mental deficiency is a contraindication to operative procedures on the extremities On the other hand even in the presence of feeblemindedness operations are justified if it is felt that the patient can be made to walk

4 In patients with low mental status the operation of choice is one which does not require a long and intensive progra muscle training

5 It is of prime importance to rec not only the spastic muscles but als power of and control of all muscles c extremities particularly the antagoni the spastic muscles. The antagonists exhibit marked weakness and for pra purposes a complete flaccid paralysi noted previously flaccidity may result a cerebral lesion In the presence of fl muscles the difficulty of the patient wi be eliminated by relieving spasticity C other hand a muscle weakened by cor stretching will regain power when th forming element is removed

6 Age is a delimiting factor certai erations are permissible in young pa in order to eliminate deformities an hance function. However this must be sidered as a temporary measure be subsequent surgical procedures may be essary when the child is older

CORRECTION OF DEFORMITIE THE KNEE IN SPASTIC PARAL

Flexion contracture is the usual de ity encountered in the knee joint It i result of impaired balance between th tensor and the flexor muscles how occasionally the deformity may be a comitant feature of adduction flexion formities at the hip joint The opera usually employed to overcome this def ity comprise lengthening of the hams tendons displacement of a high patella lower level in cases of a stretched and quadriceps and division of the patellar nacula In some cases improvement o and knee extension in walking may b tained by transference of the hams tendons to the femoral condyles Sc neurectomies and transference of the l strings to the patella have failed to ach the desired results and hence are ra employed

In the spastic group hyperexten ion

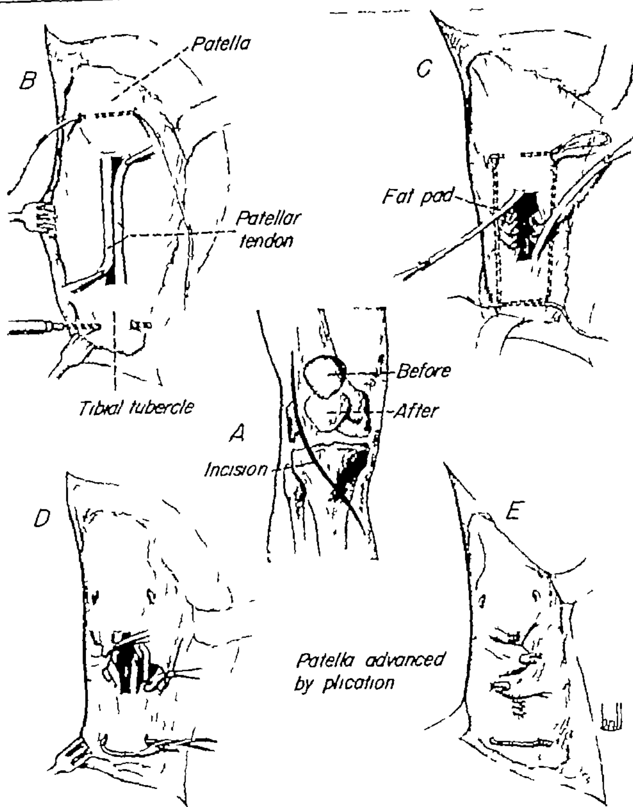


FIG 249 Chandler's operation for advancement of the patella. (Redrawn from Chandler J Internat. Coll Surgeons 3 434)

formities of the knee are usually the result of an equinus deformity of the foot with a short tendo achillis associated with imbalance between the extensor and the flexor muscles of the knee This deformity may also arise subsequent to operative procedures such as tenotomy or lengthening of the hamstrings or as a complication to dis

turbance of growth of the proximal epiphyseal plate of the tibia following trauma or operative procedures in this region.

ADVANCEMENT OF PATELLA IN SPASTIC PARALYSIS (CHANDLER)

In the small group of cases of spastic paralysis with flexion contractures of the knee joint the usual surgical measures such as lengthening or tenotomy of the hamstrings neurectomy of the flexors or posterior capsulotomy of the knee joint will not correct the deformity In these cases the patient stands and walks with the knee partially flexed active extension of the knee is possible to 160° although the knee in some instances can be extended passively to a position of complete extension Examination of the extensor apparatus discloses that the patella occupies a position opposite the lower shaft of the femur proximal to its normal anatomic location Also upon flexing the knee the patella rides high on the femoral condyles producing an angular configuration of the knee joint the patellar tendon is abnormally long and prominent anteriorly In the presence of these abnormalities the mechanics of the quadriceps are so altered that the last few degrees of extension cannot be attained even when the posterior structures offer no resistance

To obtain complete and active extension Chandler devised an operation to advance the patella to a lower level by reattaching the tibial tubercle with the patellar tendon attached to a lower level on the anterior surface of the tibia This procedure reestablishes normal leverage and permits the quadriceps to extend the knee joint completely In the event that the posterior structures offer resistance to correction this obstruction must first be overcome by stretching by wedging casts by lengthening of the hamstrings or by posterior capsulotomy of the knee joint Although this procedure produces the desired results the anterior portion of the proximal tibial epiphysis may be disturbed sufficiently to cause an arrest of growth resulting in genu recurvatum Hence the originator redesigned the method wherein the patella is advanced without disturbing the bony parts of the upper end of the tibia the operation comprises shortening the patellar tendon by reefing and plication

TECHNIC (Fig 249)

A curved skin incision exposes the patellar tendon It begins on the lateral side of the patella 1 inch proximal to its upper border and curves distally and medially crossing the distal portion of the tendon it ends on the anteromedial aspect of the tibia 1 inch below the tibial tubercle After the superficial fascia is divided the flaps are retracted to either side bringing into view the patella and the patellar tendon The center of the patella is drilled transversely and a stainless steel wire is inserted a second transverse drill hole is made through the crest of the tibia immediately below the tibial tubercle (Fig 249 B) A curved cannula is inserted beneath the aponeurosis opposite the lateral opening of the tibial drill hole and is forced proximally under the aponeurosis to emerge opposite the lateral opening of the drill hole in the patella The lateral segment of the wire is inserted into the lumen of the cannula and then the cannula is withdrawn A similar procedure is executed on the medial side and both ends of the wire are then passed through the hole in the tibia (Fig 249 C) A vertical incision is made in the mid line of the patellar tendon and narrow strips of tendon are cut from its free margins one strip retains its attachment to the patella and the other to the tibia (Fig 249 C) By drawing on its ends the wire is made taut and the patella assumes a normal anatomic position in relation to the joint line this position is maintained by twisting the ends of the wire (Fig 249 D) Using a fascia needle the strips of tendon are passed through the redundant

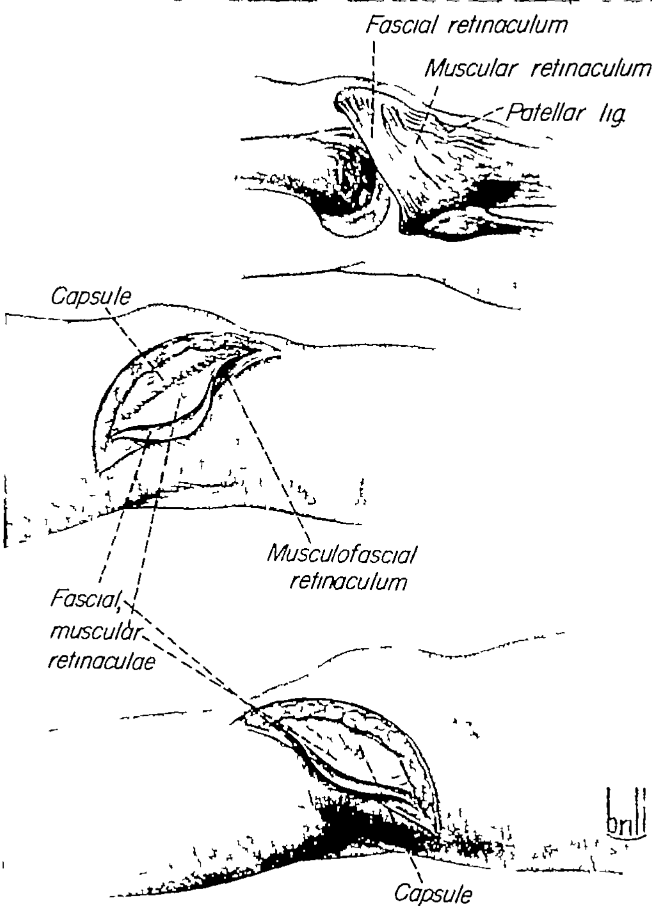


FIG 250 Division of the patellar retinacula (Eggers) (*Top*) Contracted structures limiting extension. (*Center*) Division of the lateral retinaculum (*Bottom*) Division of medial retinaculum.

patellar tendon and then fixed to the opposite portion of the tendon. The plicated tendon is fixed with interrupted silk or cotton sutures (*Fig 249 E*)

At the termination of the operation an *elastic* compression bandage is applied, and the limb is immobilized in a posterior plaster splint After the surgical reaction subsides (4 to 5 days) the splint is removed and active motion is commenced After 8 to 10 weeks the wire is withdrawn

DIVISION OF THE PATELLAR RETINACULA (EGGERS)

According to Eggers, division of the patellar retinacula has some distinct advantages over transference of the tibial tubercle distally or shortening the patellar tendon The author s experience with this method has been most gratifying The advantages are the simplicity of the procedure the short period of healing physiologic shortening of the quadriceps and early ambulation In addition damage to the upper tibial epiphysis is avoided The operation is based on the anatomic arrangement of the patellar retinacula on the medial and the lateral aspects of the knee joint Immediately above the knee joint the fibers of the fascia lata extend to the medial and the lateral borders of the patella. On the lateral side these fibers are also continuous with the iliotibial band and ultimately gain attachment to the lateral condyle of the tibia in front of the proximal tibulofibular joint Distally the fascia lata blends with the deep fascia and the intermuscular septa and inserts into the tibia and the fibula and blends with the tendons crossing the knee joint On the medial side the fascia lata blends with the tendons of the gracilis the sartorius and the semitendinosus muscles In addition the fascia lata blends with the tendinous slips of insertion of the vasti

Under normal conditions extension of the knee is accomplished primarily by pull of the quadriceps on the tibial tubercle through the patellar tendon and secondarily through the retinacula, which comprises fibers from the fascia lata and fibers of insertion of the vasti these fibers insert into the tibia and the fibula. It becomes apparent that the lateral expansions of the extensor apparatus play a significant role in extension of the knee joint In the flexed knee of the spastic the patellar ligament becomes elongated and the degree of stretching in the lateral and the medial retinacula becomes progressively less as the radial center is approached Hence the retinacula medial and lateral to the mid line preclude complete extension of the knee joint When extension of the knee is attempted contraction of the quadriceps does not exert its final pull on the tuberosity of the tibia but rather on the retinacula which are contracted and prevent complete extension It becomes obvious that division or elongation of the medial and the lateral retinacula should permit full extension by physiologically shortening the quadriceps. *The procedure should be done in combination with transference of the hamstring tendons to the femoral condyles in order to* improve extension of the hip joint

TECHNIC (Fig 250)

After the hamstrings are transplanted to the femoral condyles the patient is placed in a supine position with the knees in extension One half inch lateral to the outer margin of the patella a skin incision 3 inches in length is made beginning at a point midway between the distal end of the patella and the tuberosity of the tibia It extends upward paralleling the lateral border of the patella The skin flaps are retracted to either side exposing the fascial retinaculum which is cut parallel with the patellar ligament and the patella this incision then curves posteriorly and terminates immediately in front of the femoral attachment of the fibular collateral ligament In executing this step the iliotibial band is severed The muscular retinaculum lying immediately beneath the fascial reti

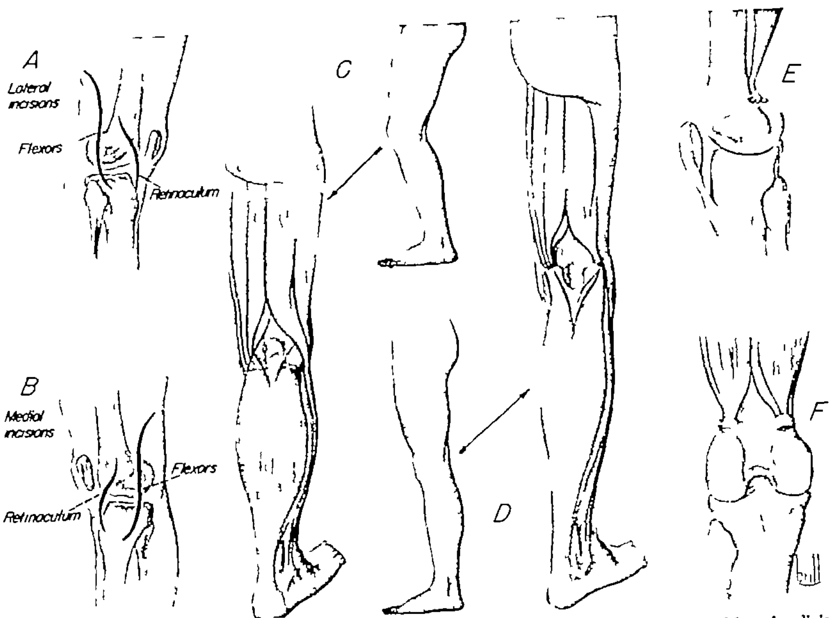


FIG 251 Transplantation of the hamstrings to the condyles of the femur (Eggers) (A, B) Incisions for division of the patellar retinacula and exposure of the hamstring tendons. (C D) The hamstring tendons are divided (E, F) The ends of the tendons are anchored in subperiosteal tunnels in the posterior lateral and the posterior medial aspects of the lateral and the medial femoral condyles, respectively

naculum is divided in the same line of incision division of this last structure brings into view the capsule of the joint which is left intact

A second incision similar to the first is made on the medial side of the knee joint it begins ½ inch medial to the inner border of the patella and continues proximally for a distance of 3 inches The fascial retinaculum is cut parallel with the patellar tendon and the patella and then sweeps posteriorly as far as the point of the femoral attachment of the tibial collateral ligament The muscular retinaculum is divided in the same line of incision as on the lateral side the capsule of the joint is visualized but not divided The incision in the retinacula is left open and the skin edges are approximated by interrupted sutures

TRANSPLANTATION OF HAMSTRING TENDONS TO FEMORAL CONDYLES IN SPASTIC PARALYSIS (EGGERS)

This procedure was designed by Eggers to improve walking in cases of spastic paralysis with flexion deformities of the hips and the knees When used in combination with release of the retinacula hip extension is improved and knee flexion is overcome The aforementioned observer points out that when flexion of the knee is corrected without improving extension at the hip the patient exhibits flexion of the hip and the knee in dynamic walking When walking with the hips flexed compensatory flexion of the knees occurs Hence in these cases *it becomes obvious that in order to improve* the dynamic gait improvement of hip extension in addition to correcting flexion deformities of the knees is essential As noted previously knee flexion can be corrected by release of the patellar retinaculum hip extension can be improved by transference of the hamstring tendons to the *femoral* condyles By this procedure the hamstring muscles function as extensors of the hip and indirectly retain extension of the knee By not disturbing the popliteus the gastrocnemius and the sartorius muscles provided that they are functionally active recurvatum of the knee joint is prevented

Technic (Fig 251)

With the patient in a prone position a vertical "S incision 3 in long is made over the tendon of the biceps femoris muscle its distal limb curves anteriorly just above the head of the fibula The skin edges are retracted medially and laterally and the tendon of the biceps and the common peroneal nerve are identified the tendon is divided just before it gains attachment to the head of the fibula proximal to its point of bifurcation The tendon is passed through and anchored in a periosteal tunnel made on the posterolateral margin of the lateral femoral condyle It is essential that the medial side of the tendon rests well in the grooves in order to ensure an osseous attachment

A second incision, similar to the first, is made on the posteromedial aspect of the *knee joint posterior to the sartorius muscle* The medial hamstring tendons the gracilis the semitendinosus and the semimembranosus are severed ½ inch from their insertion into the tibia and are anchored in a subperiosteal tunnel made on the posteromedial aspect of the medial condyle of the femur The ends of the tendons are sutured to the fibrous tissue in this region the tendons should be in apposition to raw bone to permit bony fixation The wounds are closed in the usual manner

At the termination of the operation the *extremity* is immobilized in a plaster cast extending from the groin to the toes The cast is removed at the end of 3 weeks and walking instructions are instituted The optimum results are usually manifest at the end of 1 year Eggers recommends that release of the patellar retinacula not be *done unless the hamstrings are transplanted* to the femoral condyles these procedures are interdependent and when used in com

bination, produce the most satisfactory results. If talipes equinus is present, a neurectomy of the soleus muscles through a lateral approach is advisable Lengthening of the heel cord is seldom necessary after soleus neurectomy

NEURECTOMY OF THE SOLEUS MUSCLE

With the patient in a prone position a slightly curved incision 4 inches in length is made on the lateral aspect of the leg posterior to the head of the fibula, it begins at the neck of the fibula and extends distally The common peroneal nerve is identified and protected The interval between the gastrocnemius and the soleus is developed, and the gastrocnemius is displaced posteriorly, exposing the posterior aspect of the soleus On the posteromedial aspect of the soleus a triangular mass of fat is visualized it contains the main muscular nerves to the muscle. These usually comprise two nerves with or without a single trunk The nerves are divided, or a small segment of each may be resected The wound is closed in the usual manner

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8

Traumatic Lesions of the Ligamen

GENERAL CONSIDERATIONS

The high incidence of injuries to the ligaments encountered during World War II and the increasing number of cases resulting from organized strenuous athletics and from skiing have been responsible for the crystallization of certain concepts relative to the functional mechanics of the ligaments of the knee joint and of methods of treatment which result in maximum restoration of function It is becoming more and more apparent that the successful outcome of every case of severe injury to the ligamentous apparatus is governed by (1) immediate and accurate appraisal of the extent of the lesion (2) the institution of a program of treatment which strives to restore completely the normal anatomy of the affected ligaments and (3) the redevelopment of the quadriceps apparatus to the equivalent of or even better than that of the normal limb Failure to understand the true nature of severe injuries or lack of comprehension on the part of the examiner of the role that the damaged structures play in the over all performance of the knee joint too often leads to inadequate treatment Usually a plaster cylinder is applied for 4 to 6 weeks believing that complete fixation will allow adequate healing of the implicated soft tissues Such a program of therapy does no harm in cases with minor sprains of the various components of the ligamentous apparatus and of the capsule however irreparable harm may be done in cases with severe lesions such as complete ruptures of the tibial collateral ligament which lesion is commonly associated with a rupture of the anterior cruciate ligament and tearing of the internal menisc author s experience, immediate su pair of ligaments extensively da far superior to conservative measu surgical intervention in competent sults in a higher incidence of good ing knees which are capable of me rigorous demands of youth. Fi achieve early repair of implicated l too often results in a weak unst which is constantly ' giving way " an ling " The repeated traumata pro current effusions and chronic villo vitis eventually osteoarthritic al of varying intensity supervene

Both the anterior cruciate and t collateral ligament act as checkrei duction and external rotation of on the fixed femur The effect of straining force is definitely more pro when both ligaments are intact th they act singly hence in fresh every effort should be made to re continuity of these ligaments If l torn it is wrong to be satisfied witl ing only the tibial collateral ligam lieving that this procedure is suffi provide adequate stability of the flexion As noted above stability hanced further if both ligaments stored this should be the goal o surgeon who assumes the responsil the treatment of ligamentous lesion knee joint The added surgical diffic achieve this aim should not be d factors

Some brilliant results have been r in the military service by the use servative measures in cases of seve mentous damage This has not been

perience of the writer or the experience of some other workers who find themselves in a position to observe and treat a sufficient number of cases to qualify them to express an opinion based on clinical experience It was the author s good fortune to be assigned in World War II to a Marine training base where the recruits were imbued with a high esprit de corps The preliminary training was unusually severe, and numerous ligamentous injuries were encountered, this invaluable material, together with cases encountered in civilian practice, permitted the author to arrive at the views presented here In these views are in agreement with such workers as Abbott, Saunders, Bost and Anderson and O'Donoghue

The anatomy and the functional mechanism of the ligaments of the knee joint have been recorded previously in Chapters 3 and 4 respectively It was pointed out that all the components of the knee joint work in harmony to produce a smoothly functioning unit this comprises the bony elements, the ligaments, the muscular apparatus the capsule and the synovialis. Impairment of one of the ligaments does not produce severe dysfunction of the joint, provided that the muscular apparatus possesses sufficient tone and power to compensate for the defect. Nevertheless, such a joint is far from normalcy and is vulnerable to minor traumata It is essential to emphasize that the ligaments like the synovialis the capsule and the muscles motorizing and crossing the knee joint are endowed with a highly specialized sensory innervation which permits them to work in unison The meticulous works of Payr and Hilton are monumental contributions elucidating this close interrelationship The synchronous function of the many ligaments and muscles of the knee joint is the result of afferent nerve impulses arising in the ligamentous apparatus which are conducted to the brain where they initiate efferent impulses which are relayed to the muscles stabilizing and activating the joint In addition this same mechanism protects the joint structures from abnormal stresses and strains and in the event of injury is responsible for the resulting muscle spasm which is nature's method of guarding and splinting the joint from further damage

It was pointed out previously that during normal joint motion the intricate mechanism of the ligaments function in such a manner that certain ligaments or portions of ligaments are tense, while others are less tense or more relaxed, allowing at the same time free motion and stability of the joint In addition, the structure the strength the method of attachment and the direction of the course of the ligaments stabilize the joint passively and by acting as checkreins determine the plane of motion of the bony elements of the joint. All the ligaments are tense only in the position of hyperextension, if lateral motion or more hyperextension is superimposed while the joint is in this position varying degrees of ligamentous damage will ensue, depending upon the severity of the force applied

In the light of this information it becomes apparent that any form of man made ligament lacking the sensory innervation described previously is a poor substitute for the normal structure hence, a normal joint must not be anticipated Such a replica may improve stability and function, but it will not perform as a live integral element of the knee joint This explains why early repair of disrupted ligaments produces better joints than late reconstruction of the implicated structures

MECHANISMS RESPONSIBLE FOR INJURIES OF THE LIGAMENTS

During normal joint function the ligaments provide passive stability to the knee joint also, the cruciate ligaments guide the paths of motion of the femoral condyles. Abnormal forces which tend to alter the normal relationship of the femoral condyles to the tibia subject the capsule and the liga

ments to stresses and strains of varying in tensity depending upon the nature and the violence of the acting force Palmer has de ciphered and described four abnormal mech anisms which are capable of producing spe cific types of injuries to the ligamentous apparatus

Abduction Flexion and Internal Rotation of the Femur on the Tibia

This constitutes the most common mech anism encountered on the football field and may result in severe damage to t ments it is also the type of viol sponsible for skiing injuries The fixed the knee is in varying de flexion and the body weight is fo ward with great impetus at the sa the femur is rotated medially and t is forced into a position of abductio 252) This mechanism tends to st the knee joint the severity of the to the ligaments depends upon the i of the subluxating force Forces o



Fig 252 Mechanism of injury of the ligaments by abduction flexion and internal rotation of the femur on the fixed tibia. Note that the foot is fixed to the ground and i unable to rotate in either direction The knee is flexed lightly and the patient s body weight is thru t inward

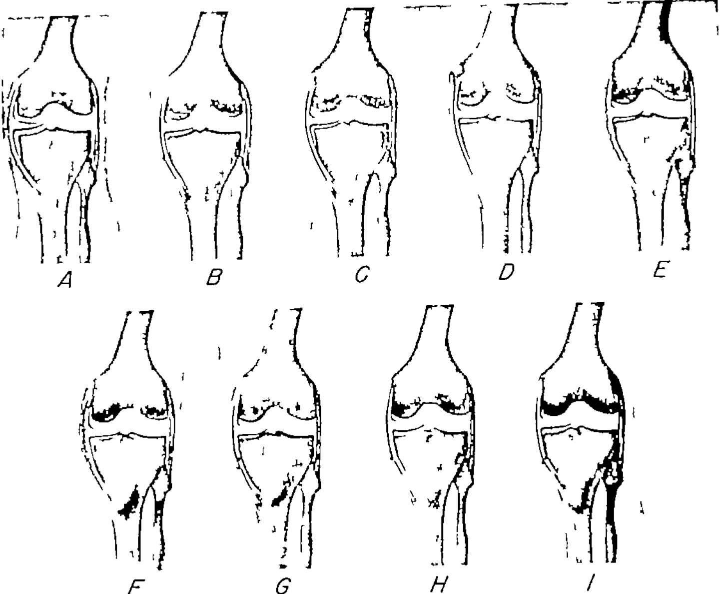


Fig 253 Isolated lesions of the tibial collateral ligament. Note that both the superficial and the deep portion of the ligament may be avulsed either from the femoral or the tibial insertions. Occasionally, a flake of bone is avulsed from the condyle of the femur at the site of the insertion of the superficial fibers.

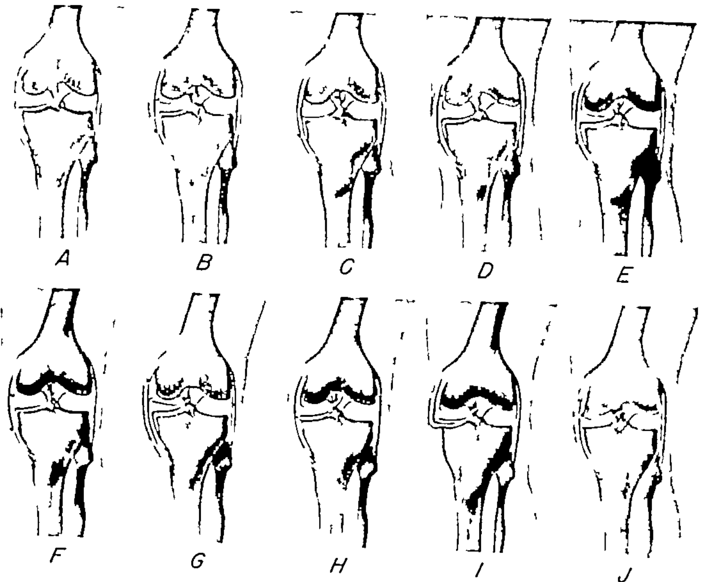


Fig 254 The various types of combined lesions encountered by the author The severity of the lesion depends upon the intensity of the force applied Note that the lesions of the tibial collateral ligament may be associated with the lesions of one of the menisci or one or both of the cruciate ligaments

intensity may implicate only the long anterior fibers of the superficial portion of the tibial collateral ligament and the vertical fibers of the deep portion, the fibers may be stretched or shredded, but the continuity of the ligament remains intact (Fig 253) Greater violence may result in disruption of the superficial and the deep portions of the tibial collateral ligament and rupture of the anterior cruciate ligament, either this structure may be torn from its femoral attachment or its fibers may be shredded and frayed as the interval between its femoral and tibial insertions is increased (Fig 254) Frequently, in addition to injuries to the tibial collateral and the anterior cruciate ligaments, the medial meniscus is injured Such a mechanism has been reported as also producing a tear of the posterior cruciate ligament (Fig 254) Occasionally this mechanism may produce a compression fracture of the outer tibial condyle in such instances the intensity of the forces acting on the ligaments is diminished apprecia hence these structures are rarely dam severely (Fig 255)

Adduction, Flexion and Externa Rotation of the Femur on the Ti

Injuries resulting from this mecha are exceedingly rare occasionally, ac tion injuries occur when the knee is ir position of full extension As in the ab tion injuries, so in the adduction lesion tibia is fixed, and the knee is flexed force is applied to the inner side of the k driving the femur into external rota The first structure to suffer the brunt o violence is the fibular collateral ligai which ruptures if the force continue act the anterior cruciate ligament anc casionally the tendon of the popl muscle are also ruptured The proximit the common peroneal nerve to the joint on the outer aspect of the knee makes structure very vulnerable and may



Fig 255 Occasionally the ligaments may escape injury when the force is expended by the tibial plateau resulting in fracture of the lateral condyle of the femur such as is depicted in this case In such instances the extent of the ligamentous damage is usually minimal

stretched or torn in adduction injuries (Fig 256)

HYPEREXTENSION

It was pointed out previously that all *ligaments and the posterior portion of the* fibrous capsule are tense when the knee is in a position of hyperextension If the knee is driven into further hyperextension u u ally as a result of a direct force applied to

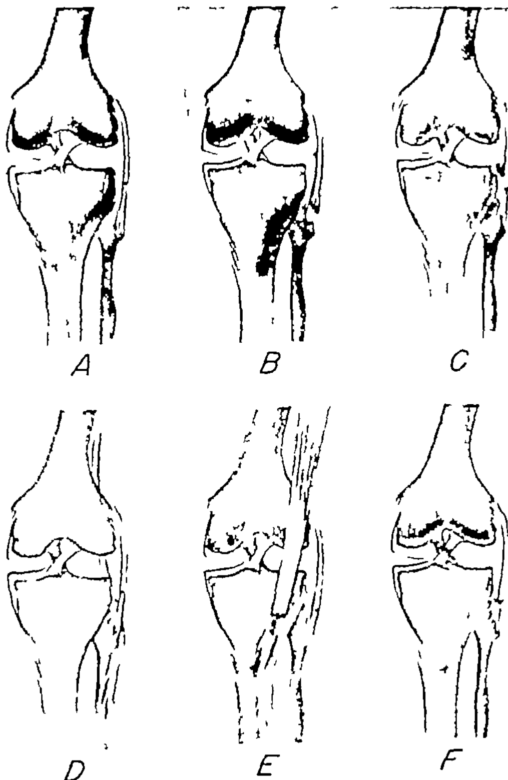


FIG 256 Types of lesions encountered when the fibular collateral ligament i implicated Occasionally a flake of bone is torn from the head of the fibula by the distal insertion of the fibular collateral ligament

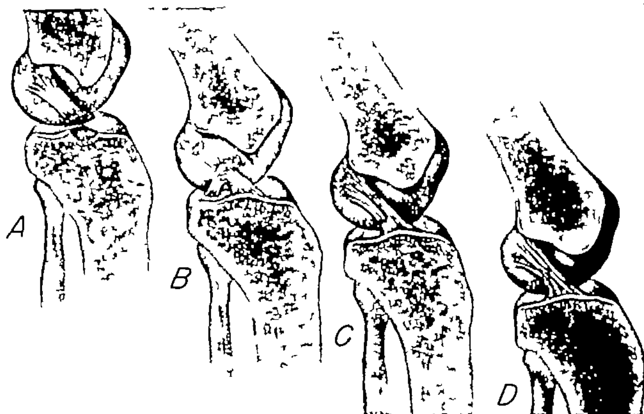


Fig 257 Types of ruptures of the anterior cruciate ligament described by Palmer Hyperextension forces may produce (A) Avulsion of the bony tibial insertion of the ligament. (B) Rupture of the ligament at its femoral insertion (C and D) Shredding and stretching of the ligament.

the anterior surface of the fixed leg the posterior portion of the capsule is stretched or even torn if the force continues, rupture of the anterior cruciate ligament may ensue This may be in the form of avulsion of the bony tibial insertion of the ligament or shredding of its fibers (Fig 257) Occasionally, this mechanism may produce stretching or tearing of some of the fibers of the posterior cruciate ligament

Anteroposterior Displacement

The posterior cruciate ligament prevents abnormal posterior displacement of the tibia on the femur if the tibia is driven backward or the femur forward while the knee is flexed, a tear of the posterior cruciate ligament occurs generally, the lesion is an avulsion of the tibial bony insertion of the ligament The detached bony fragment may be drawn into the posterior region of the intercondylar space Occasionally, the tear may occur at the femoral attachment of the ligament (Fig 258)

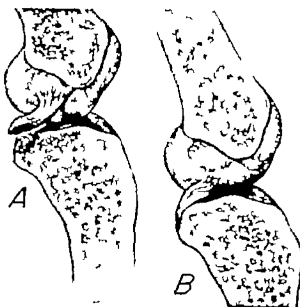


Fig 258. (A) The posterior cruciate ligament may be avulsed with a small piece of bone from the superoposterior aspect of the tibia, or (B) the ligament may be ruptured at its femoral attachment.

Forceful backward displacement of the femur with the tibia fixed and the knee flexed may result in a lesion of the anterior cruciate ligament The classical lesion is avulsion of the tibial insertion of the ligament, comparable with a fracture of the spine of the tibia

RECENT TRAUMATIC LESIONS OF THE COLLATERAL LIGAMENTS

Injuries of the Tibial Collateral Ligament

This structure is injured most frequently by abnormal forces driving the slightly flexed knee into varying degrees of abduction and at the same time rotating the femur medially on the fixed tibia As pointed out previously in this mechanism the tibial collateral ligament is the first line of defense against such subluxating violences and the severity of the injury it sustains is dependent upon the intensity of the violence *Generally the force is of minor intensity* resulting in stretching or partial avulsion of the fibers more forcible violence causes complete tearing of the ligament and often produces concomitant lesions of the anterior cruciate ligament and the internal meniscus In most instances the pronounced disability associated with severe lesions leads to an accurate evaluation of the injury however in minor lesions frequently the true nature of the lesion is not understood this failure is *responsible for inadequate treatment* which frequently is followed by the development of calcification and later new bone formation in the ligament usually in the region of its femoral attachment (Pellegrini Stieda disease)

Incomplete Ruptures (Uncomplicated) These lesions are commonly encountered in football baseball or ski ... The twisting force (abduction ... d me-

Symptoms and Signs Althoug... *may be severe at the time of* ... frequently its intensity subsides ... that the immediate disability m... slight the patients often contin... ticipate in the endeavors in whic... engaged Pain is localized over ... aspect of the knee joint, and ge... knee is held in a few degrees o... from 15° to 20 Some swelling n... cernible in the regions of the til... femoral attachments of the ligan... *tenderness can be elicited along* ... course of the long anterior fibers ... ment however invariably the ... tenderness is located at the site ... sion which in this type of lesio... frequently at the femoral atta... the fibers If some protective spa... hamstring muscles exists the pat... the knee slightly flexed and resis... and active extension of the joint ... plicated lesions this reflex are ca... *rupted readily by the injection of* ... of procaine at the site of maxi... derness now the knee can be ... completely

Because the continuity of the li... intact abnormal abduction rocki... sent while the knee is in 15 to 2... ion However with the knee exte... attempts at abduction of the le... *severe pain at the site of the le*... lateral rotation of the leg which ... *whole ligament on a stretch* pro... same result

As a rule isolated incomplete te... tibial collateral ligament are not ... with ... ion or hemarthrosis usu... indicative of other co... s Occasionally h... the joint may be ... out impli... it or the

the flexion was not caused by a displaced meniscus. In the absence of abnormal lateral motion, a positive drawer sign and mechanical blocking to full extension, one can conclude that the lesion is an incomplete tear of the tibial collateral ligament but one is unable to eliminate the possibility of a tear of the internal meniscus without displacement. Only time will enable one to make the final diagnosis.

Roentgenographic studies provide no information of value in arriving at a diagnosis unless an abduction force is acting while the roentgenograms are taken This is achieved best with the patient relaxed completely by a general anesthesia, Pentothal Sodium given intravenously is a suitable agent for this purpose A pillow is placed under the knees, flexing the joints from 15° to 20° then the knees are bound firmly together with a canvas strap or a linen bandage The feet are forced apart by sand bags hence, an abducting force is created at each knee joint. Roentgenograms of each knee are taken in the true anteroposterior view comparison of the two roentgenograms will reveal any difference in the width of the inner joint spaces. An increase in the interval between the articular surface of the medial femoral condyle and the corresponding tibial articular surface over that present in the unaffected knee is indicative of a complete tear of the tibial collateral ligament no increase points to a sprain of the ligament with its continuity remaining intact (Fig 259)

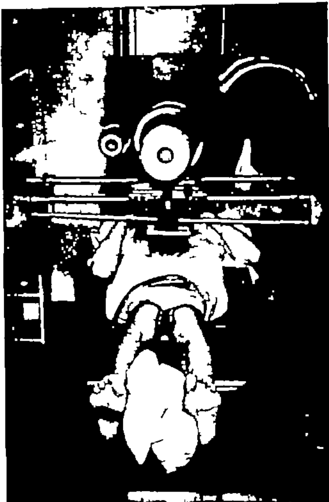


Fig 259 A method of x ray examination when lesions of the medial ligament are suspected. The knees are bound together and flexed from 15° to 20° The feet are wedged apart by sandbags. An increase of the medial joint space on the affected side is indicative of a tear of the medial collateral ligament wide separation indicates rupture of both the medial collateral and anterior cruciate ligaments.

Management Simple sprains of the tibial collateral ligament without effusion or hemarthrosis are treated most effectively by the application of a snug fitting nonpadded plaster cylinder extending from above the malleoli to the groin with the knee in the extended position If pain is severe from 3 to 5 cc. of procaine may be injected into the site *of maximum tenderness before* the plaster cylinder is applied Weight-bearing can be started immediately a wedge on the inner side of the heel tends to shift the body weight to the outer side of the knee joint. Quadriceps drill and weight lifting exercises are commenced immediately The cast is worn for 4 weeks further protection, if deemed necessary can be provided by an elastic bandage Exercises are continued until the quadriceps of the affected limb is equal in power to that of the opposite side

In cases with an associated effusion or hemarthrosis the joint is aspirated and then enveloped in a compression bandage in order to prevent recurrence of the swelling First, the knee is wrapped in sheet cotton, over this a snug elastic bandage is applied, ex

tending from the middle of the leg to the mid thigh No weight bearing is permitted, however quadriceps exercises and straight leg raising against elastic resistance are instituted at once After the effusion has subsided a plaster cylinder is applied and weight bearing is permitted The treatment from this point is the same as that described for sprain of the ligament without effusion or hemarthrosis In the latter group of cases one must bear in mind that a lesion of the meniscus may exist If clinical features consistent *with internal derangement of the* knee such as buckling or "giving way," and recurrent effusions appear after the cast has been removed and the patient has resumed his normal activities an injury of the meniscus occurring at the original injury becomes apparent

Complete Ruptures. Depending upon the severity of the rotary force acting on the slightly flexed knee with the tibia fixed numerous isolated lesions of the tibial collateral ligament are encountered The pathology of these lesions is understood readily *if the ligament is visualized shortly after* injury The most frequent alteration is a tear of the femoral insertion of the superficial long anterior fibers of the ligament next in frequency is tearing of the tibial insertion of these fibers and occasionally in the former instances a flake of bone may be avulsed from the medial aspect of the femur (Fig 253) Also the long fibers of the superficial ligament may be found shredded stretched and attenuated Frequently lesions of the deep portion of the ligament are associated with those of the superficial portion this deep structure may exhibit a tear at its tibial or femoral attachments or at its center in proximity with the periphery of the internal meniscus (Fig 253)

Clinical Features The injury always is accompanied by severe pain at the time of the accident however in many instances it *decreases rapidly in intensity so that* the individual is capable of continuing his participation in the activity at hand later the intensity of the pain increases The traumatized ligament initiates a reflex mechanism protective in nature, which forces the patient to hold the knee slightly flexed at this time involuntary spasm of the hamstring muscles precludes any active or passive attempts to straighten the knee joint This mechanism is not active immediately after the injury, and swelling resulting from effusion or hemorrhage into the joint or a local hematoma have not as yet developed so that examination at this time may reveal some pertinent information not obtainable after muscle spasm has set in and swelling of the joint has occurred One is able to localize with considerable accuracy the exact location of the lesion in the ligament this is achieved by determining the area of maximum tenderness by digital pressure (Fig 260) abnormal abduction rocking and abnormal anteroposterior displacement of the tibia on the femur are readily discernible finally the absence or the presence of any mechanical blocking to full extension can be determined

The site of maximum tenderness along *the course of the ligament* early or late after the injury invariably points to the site of the lesion Also attempts at abduction rocking invariably project pain along the inner aspect of the knee After muscle spasm has set in any abnormal motion is difficult to elicit In order to demonstrate such motion it becomes necessary to attain complete muscular relaxation this is accomplished best by a general anesthetic The author prefers Pentothal Sodium With complete rupture of the tibial collateral ligament varying degrees of abnormal lateral motion at the knee joint are demonstrable both manually and by roentgenographic examination Roentgenograms are taken with the patient under general anesthesia and the knee flexed from 15 to 20 as depicted in Figure 259 Roentgenogram of both knees should be made for comparative study rupture of the ligament *is indi*cated in the increase in width of the medial joint as compared with the normal side It was recorded previously in the mechanic of

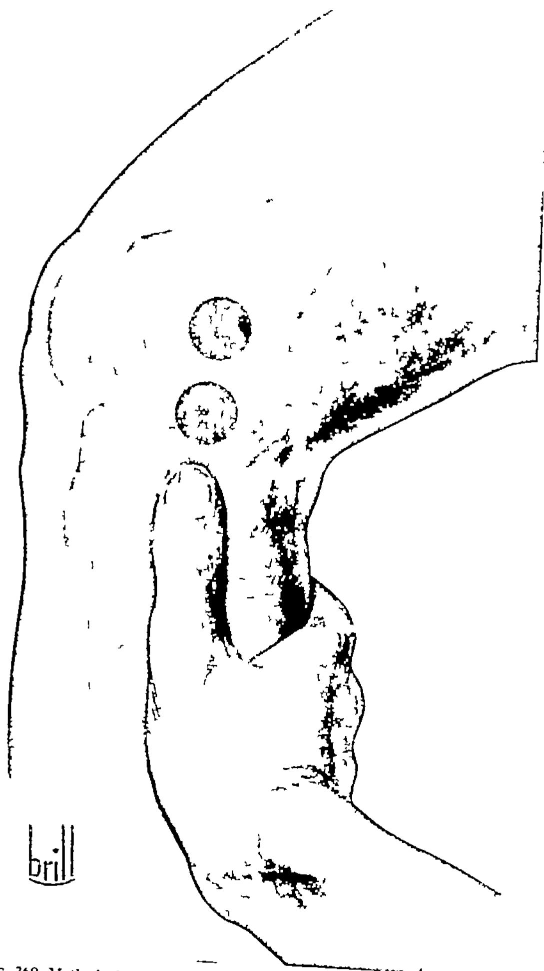


Fig 260 Method of examination of the tibial collateral ligament The site of maximum tenderness usually indicates the portion of the ligament involved

the knee joint that no abduction rocking is possible with the knee in hyperextension because the intertwining of the cruciate ligaments and the increased tension in these ligaments preclude such abnormal motion this is true even when the tibial collateral ligament is divided It becomes apparent that if lateral motion exists with the knee in the hyperextended position a rupture of the anterior cruciate ligament must exist as a concomitant lesion of rupture of the tibial collateral ligament Such abnormal motion is not possible in isolated lesions of the tibial collateral ligament

Careful palpation of the medial aspect of the knee joint may reveal if present a small particle of bone comprising the femoral insertion of the ligament also a palpable irregular tumefaction along the course of the ligament may indicate curling up of the ruptured end of either the superior or the inferior segments of the long anterior portion of the tibial collateral ligament

Some cases of isolated lesions first seen from 12 to 24 hours after the injury may reveal swelling of the joint resulting from an effusion or a hemarthrosis. These features invariably indicate some implication of the deep fibers and tearing of the synovialis above or below the superior rim of the internal meniscus Intra-articular fluid adds to the difficulty of the diagnosis relative to the presence or the absence of injuries to the meniscus or the anterior cruciate ligament Synovial effusions blood or a mixture of both per se may prevent complete extension of the joint both actively or passively also they may initiate a reflex mechanism in which spasm of the hamstring muscles precludes voluntary extension of the joint thereby making it impossible to eliminate the possibility of a displaced meniscus as the causative factor responsible for blocking complete extension Aspiration of the joint or examination of the limb with the patient under a general anesthesia usually clarifies the situation In the absence of blood or synovial effusion in the joint cavity, the joint can be extended readily following infiltration of the area of maximum tenderness with procaine provided that a mechanical block caused by a displaced meniscus does not exist.

It must be emphasized at this point that isolated ruptures of the tibial collateral ligament produce only a minimal spread of the medial articular surfaces of the tibia and the femur when examined by the aforementioned methods or by roentgenographic study Marked abduction rocking of the tibia with the knee in slight flexion and a positive drawer sign are findings consistent with a rupture of the anterior cruciate ligament

Complete Rupture with Coexisting Lesions. Concomitant lesions with complete rupture of the tibial collateral ligament are encountered frequently the structures usually implicated are the anterior cruciate ligament and the internal meniscus Of all the numerous varieties of combined lesions of the ligaments of the knee joint this triad constitutes the most common disorder The mechanism responsible for the combined injury is similar to that described for isolated lesions of the tibial collateral ligament however the subluxating force is of much greater violence After dissolution of the tibial collateral ligament (both the superficial and the deep portions) continuation of the force results in stretching or complete rupture of the anterior cruciate ligament Frequently the meniscus is torn from its peripheral attachment to the fibrous capsule and the deep fibers of the tibial collateral ligament or it sustains a tear in its substance it may be displaced toward the center of the joint causing true locking As pointed out by O Donoghue occasionally the semitendinosus and the sartorius tendons may be avulsed from their tibial insertions and retract to a more proximal position The author has encountered 3 cases with tearing and retraction of the aforementioned tendons Routine visualization of

these lesions usually discloses the pathology to be more extensive than one generally realizes The tibial attachment of the long fibers of the superficial portion of the tibial collateral may be torn from its insertion and sucked into the joint, lying beneath the meniscus, the meniscus may be completely detached from its peripheral capsular attachments and may be displaced into the center of the joint or it may exhibit a large longitudinal tear traversing its substance as far as its anterior segment, with the central portion displaced into the center of the joint All types of combined lesions of the superficial and the deep portions may be encountered (Fig 254) This same mechanism may be responsible for dissolution of both the anterior and the posterior cruciate ligaments

Clinical Features Generally the immediate disability is greater in combined lesions than in isolated lesions of the tibial collateral ligament If the patient is examined immediately after the injury before spasm of the muscles and swelling of the joint occur the true nature of the disorder may be determined Pain is localized over the inner aspect of the joint and digital pressure readily localizes the area of maximum tenderness which usually corresponds to the site of greatest damage to the tibial collateral ligament Abnormal abduction rocking with the knee extended and extensive lateral motion with the knee in slight flexion indicate a tear of both the tibial collateral ligament and the anterior cruciate ligament

At this time it is difficult to evaluate the status of the internal meniscus unless the structure is torn and displaced into the center of the joint thereby causing a mechanical block to full extension While per

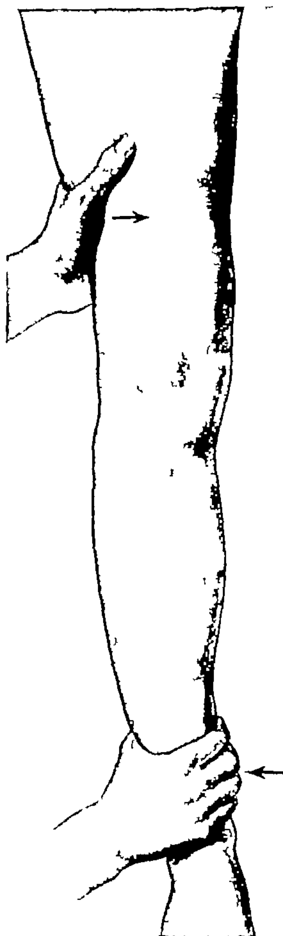


Fig 261 Clinical maneuvers permitting diagnosis of combined lesions of the tibial collateral ligament. (A) Maneuver to elicit abnormal abduction rocking with the knee extended. This is indicative of a lesion of the anterior cruciate ligament.

the knee joint that no abduction rocking is possible with the knee in hyperextension because the intertwining of the cruciate ligaments and the increased tension in these ligaments preclude such abnormal motion this is true even when the tibial collateral ligament is divided It becomes apparent that if lateral motion exists with the knee in the hyperextended position a rupture of the anterior cruciate ligament must exist as a concomitant lesion of rupture of the tibial collateral ligament. Such abnormal motion is not possible in isolated lesions of the tibial collateral ligament

Careful palpation of the medial aspect of the knee joint may reveal, if present a small particle of bone comprising the femoral insertion of the ligament also a palpable irregular tumefaction along the course of the ligament may indicate curling up of the ruptured end of either the superior or the inferior segments of the long anterior portion of the tibial collateral ligament.

Some cases of isolated lesions first seen from 12 to 24 hours after the injury may reveal swelling of the joint resulting from an effusion or a hemarthrosis These features invariably indicate some implication of the deep fibers and tearing of the synovialis above or below the superior rim of the internal meniscus Intra articular fluid adds to the difficulty of the diagnosis relative to the presence or the absence of injuries to the meniscus or the anterior cruciate ligament Synovial effusions blood or a mixture of both per se may prevent complete extension of the joint both actively or passively also they may initiate a reflex mechanism in which spasm of the hamstring muscles precludes voluntary extension of the joint thereby making it impossible to eliminate the possibility of a displaced meniscus as the causative factor responsible for blocking complete extension Aspiration of the joint or examination of the limb with the patient under a general anesthesia usually clarifies the situation In the absence of blood or synovial effusion in t cavity the joint can be extended following infiltration of the area mum tenderness with procaine that a mechanical block caused b placed meniscus does not exist.

It must be emphasized at this p isolated ruptures of the tibial collat ment produce only a minimal sprea medial articular surfaces of the t the femur when examined by the a tioned methods or by roentgen study Marked abduction rocking tibia with the knee in slight flexio positive drawer sign are findings c with a rupture of the anterior cruc ment.

Complete Rupture with Co Lesions. Concomitant lesions with c rupture of the tibial collateral ligar encountered frequently the structu ally implicated are the anterior ligament and the internal meniscu the numerous varieties of combined of the ligaments of the knee joint, t constitutes the most common disor mechanism responsible for the comb jury is similar to that described for lesions of the tibial collateral li however the subluxating force is greater violence After dissolution tibial collateral ligament (both th ficial and the deep portions) cont of the force results in stretching or c rupture of the anterior cruciate li Frequently the meniscus is torn peripheral attachment to the fibrous and the deep fibers of the tibial c ligament or it sustains a tear in stance It may be displaced toward ter of the joint causing true lock pointed out by O Donoghue occa the semitendinosus and the sartor dons may be avulsed from their tib tions and retract to a more proxim tion The author has encountered with tearing and retraction of the af tioned tendons Routine visualiza

these lesions usually discloses the pathology to be more extensive than one generally realizes The tibial attachment of the long fibers of the superficial portion of the tibial collateral may be torn from its insertion and sucked into the joint, lying beneath the meniscus the meniscus may be completely detached from its peripheral capsular attachments and may be displaced into the center of the joint or it may exhibit a large longitudinal tear traversing its sub tance as far as its anterior segment, with the central portion displaced into the center of the joint All types of combined lesions of the superficial and the deep portions may be encountered (Fig 254) This same mechanism may be responsible for dissolution of both the anterior and the posterior cruciate ligaments.

Clinical Features Generally, the immediate disability is greater in combined lesions than in isolated lesions of the tibial collateral ligament If the patient is examined immediately after the injury before spasm of the muscles and swelling of the joint occur, the true nature of the disorder may be determined Pain is localized over the inner aspect of the joint, and digital pressure readily localizes the area of maximum tenderness which usually corresponds to the site of greatest damage to the tibial collateral ligament Abnormal abduction rocking with the knee extended and extensive lateral motion with the knee in slight flexion indicate a tear of both the tibial collateral ligament and the anterior cruciate ligament

At this time it is difficult to evaluate the status of the internal meniscus unless the structure is torn and displaced into the center of the joint thereby causing a mechanical block to full extension While per

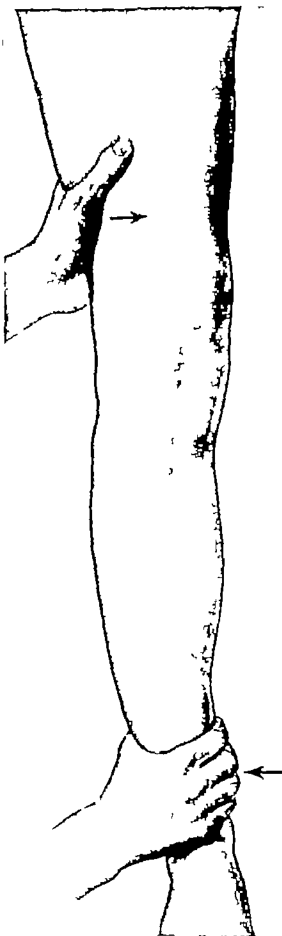


Fig 261 Clinical maneuvers permitting diagnosis of combined lesions of the tibial collateral ligament. (A) Maneuver to elicit abnormal abduction rocking with the knee extended. This is indicative lesion of the anterior cruciate ligament.

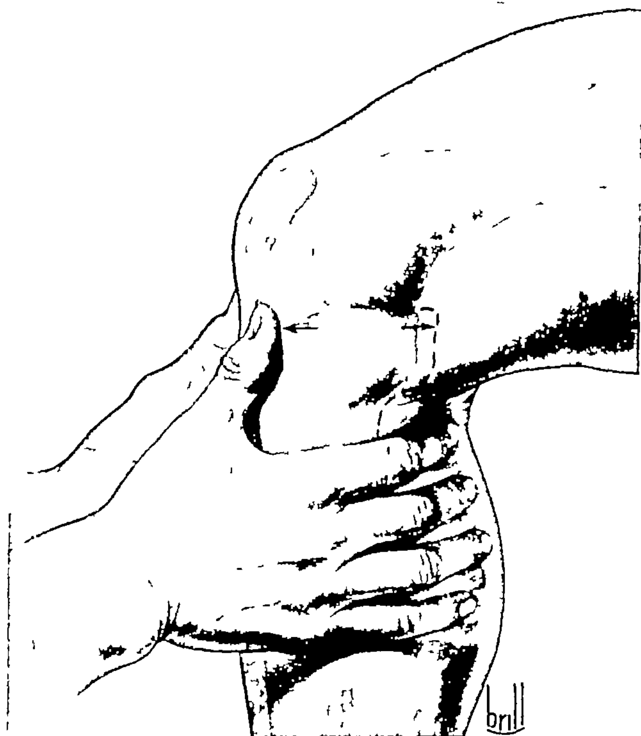


FIG. 261 (B) Method of examination of the knee joint for the presence of the "drawer sign With the knee flexed at 90 and the femur fixed anterior displacement of the tibia indicates a positive anterior draw sign posterior displacement indicates a positive posterior draw sign The former indicates a lesion of the anterior cruciate ligament and the latter a lesion of the posterior cruciate ligament

forming the abduction tests severe pain always is elicited on the inner aspect of the knee A positive drawer sign is clinical evidence of a stretched or ruptured anterior cruciate ligament (Fig 261) As noted previously in the presence of an effusion and blood within the joint the above examination of the limb is performed best under

general anesthesia Roentgenograms taken in the anteroposterior position with the knees bound together and flexed from 15° to 20° and the legs abducted by wedging a sandbag between the feet will exhibit widening of the medial joint space on the affected side

MANAGEMENT The author has encountered too many knees with severe permanent dysfunction resulting from conservative and inadequate *surgical methods* of treatment following injuries to the ligamentous apparatus of the knee joint As noted previously, it is impossible to evaluate correctly the exact extent of the damage suffered by the tibial collateral ligament in isolated lesions of this structure and in some instances it is impossible to rule out with certainty coexisting lesions of the internal meniscus In combined injuries the pathology is so extensive that it is impossible to determine the true nature of the lesion by clinical or roentgenographic studies alone Moreover long period follow up surveys reveal conclusively that immediate repair of the implicated structures yields far better results than reconstruction of the structures at a later date It becomes obvious that every case of complete rupture of the ligament with or without coexisting lesions should be investigated surgically the severity of the pathology should be evaluated and an attempt should be made to restore the continuity of all the ligaments involved

Some observers are of the opinion that in instances of rupture of both the tibial collateral and the anterior cruciate ligaments repair of the tibial collateral ligament alone will suffice provided that the quadriceps is developed sufficiently to compensate for the defective anterior cruciate ligament All agree that in such instances a good stable knee can be anticipated however one must not underestimate the role of the anterior cruciate ligament in the functional mechanics of the knee joint Clinical experience reveals emphatically that joints in which both ligaments are restored function more efficiently than in those in which only the tibial collateral ligament is repaired Many young men in the former group resume their athletic pursuits, this is rarely achieved in the latter group It is true that in some cases of severe ligamentous injuries treated by surgical repair a perfect result is not obtained, nevertheless, the goal of every surgeon should be anatomic restoration of all the torn structures in all cases, only by this *method can one hope to raise the incidence* of good long term results The added surgery to achieve this goal should not be a determining factor in the choice of methods of treatment In the hands of competent surgeons the repair of one or both cruciate ligaments and removal of the internal meniscus in addition to repair of the tibial collateral ligament is not a formidable procedure, and the additional operating time is not excessive

In the absence of complicating factors, the operation should be performed as soon after the injury as circumstances dictate. Deferment of the procedure for several days or a week alters the physical status of the local tissues to such an extent that the normal anatomic feature of the individual structures may be lost The tissues become edematous and laden with blood and tissue fluids they become friable and are covered with organizing blood clots and granulation tissue. Sutures in such tissues tend to pull out All these factors add to the technical difficulties of the operation The application of a tourniquet around the upper one third of the thigh after the limb has been emptied of blood by an Esmarch bandage will provide a dry surgical field and facilitate identification of the structures on the medial aspect of the joint

Repair of Tibial Collateral Ligament (Isolated Lesions) In order to visualize the total extent of the damage the entire ligament should be exposed by an adequate incision. The incision described herein permits the surgeon to expose the structure without undue traction of tissues which already have been traumatized severely The

tissues should be handled with meticulous care in order to prevent further vascular impairment.

The limb should be positioned properly and draped so that it may be manipulated freely without fear of contaminating the wound by exposing unsterile parts The patient lies in the supine position with a small sandbag under the knee to flex it from 15 to 20 After the skin has been prepared the entire leg is enclosed in sterile stockinet, extending from the toes to the groin which is fastened by several layers of sterile gauze wrapped tightly around the upper one third of the thigh The skin incision is made through the stockinet the cut edges of which are fastened to the corresponding wound edges by Michel skin clips

An 'S -shaped skin incision is made on the anteromedial aspect of the knee It begins 2 cm above the medial femoral epicondyle and terminates on the anteromedial surface of the tibia approximately 8 cm. below the articular margin of the inner tibial condyle The investing deep fascia is now exposed and divided by a vertical incision extending the full length of the skin incision (Fig 262) Retraction of the edges of the fascia brings into view the entire collateral ligament now the severity of the injury can be fully understood Careful inspection of the entire ligament is the next step Invariably, the discoloration of the fibers resulting from the existing hematoma provides a clue to the site of the tear generally it is at the femoral insertion but it may be at the tibial insertion. Occasionally at the former site a fragment of bone may be avulsed from the femur the superior end of the ligament still attached to this fragment lies free directly under the investing fascia At this stage of the operation the superficial portion of the ligament is gently retracted medially and the deep portion is

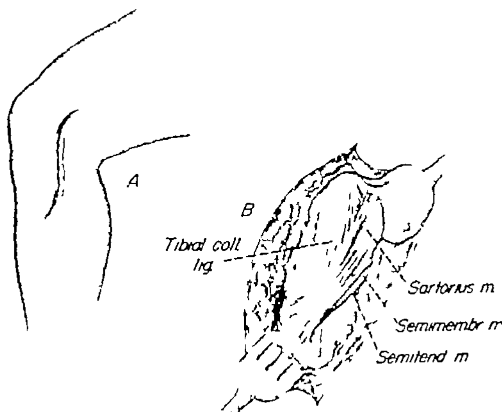


Fig 262 (A) Skin incision employed to expose the tibial collateral ligament throughout the entire length (B) Note the relation of the medial ligament to the insertion of the sartorius muscle

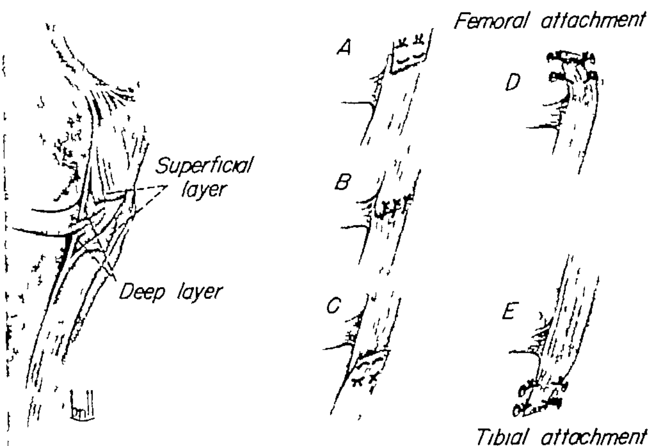


FIG 263 Method of repair of lesions of the deep portions of the tibial collateral ligament. At levels A B, C The continuity of the ligament may be restored by interrupted sutures approximating the torn ends. (D) The femoral attachment may be anchored for a slot in the femur (E) The tibial attachment may be sutured in a slot end in the tibia.

inspected the entire width of the ligament should be scrutinized both the anterior and the posterior portions of the structure Lateral rocking of the tibia on the femur facilitates the localization of the tear, when this maneuver is performed if a tear exists in either the superficial or the deep portions of the ligament a gap is readily discernible between the torn edges. Frequently the deep portion exhibits an irregular oblique tear beginning anteriorly on the anteromedial aspect of the femur and extending obliquely downward and backward across the joint to the posteromedial aspect of the tibia.

In the event that both portions of the ligament are torn the deep layer is repaired first (Fig 263) A ragged tear across the joint line can be closed readily by approximating the edges with interrupted cotton sutures However, if the ligament has been avulsed from either its femoral or tibial insertion, a new bony anchorage should be provided for the detached end This is best achieved by cutting out of the side of the femur or the tibia at the new site of attachment of the ligament a slot measuring 1 by 2 cm small drill holes are made on both sides of the slot The ligament is laid in its new bony bed and fastened to its sides by interrupted cotton sutures passing through the ligament and the drill holes

Reattachment of the femoral or the tibial insertion of the superficial layer is accomplished by fastening the torn end to its anatomic position with interrupted cotton sutures passing through the soft tissue and the periosteum If this type of repair ap-

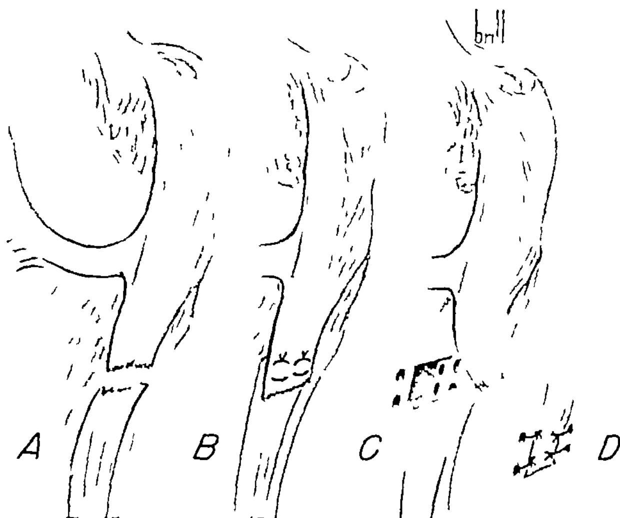


Fig 264 Method of repair of lesions of the superficial fibers of the tibial collateral ligament (A B) The ends of the ligament may be approximated by interrupted sutures. (C D) The end of the ligament may be given a new bone attachment

pears to be insecure the end may be anchored to the adjacent bone in a similar manner as that described for the repair of the deep layer of the ligament Occasionally it may be necessary to tighten the ligament by imbrication in order to achieve the desired degree of tautness Care should be taken in all instances not to obliterate the gliding mechanism between the long anterior fibers of the tibial collateral ligament and the tibia and the femur Destruction of this gliding mechanism will lead to impairment of flexion of the knee joint If a large fragment of bone has been avulsed by the femoral attachment it is replaced in its anatomic position and fixed in situ by a single screw if the fragment is small it is excised and the end of the ligament is anchored to the adjacent bone by the procedure described previously (Fig 264)

Operative Repair in Combined Lesions. The skin incision is similar to that described for repair of isolated lesions of the tibial collateral ligament (Fig 265 A B) After the entire extent of the tibial collateral has been explored thoroughly and the severity of the damage has been evaluated the interior of the joint is inspected This is accomplished by reflecting the outer skin flap until the parapatellar region is exposed then a parapatellar incision is made through the capsule and the synovialis thereby gain

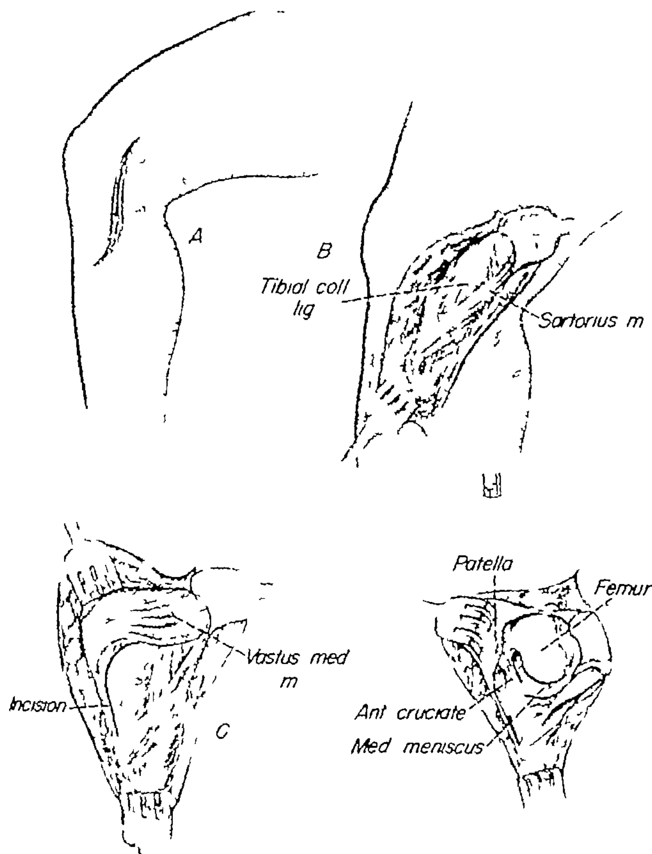


FIG 265 Exploration of the tibial collateral ligament and method of exposure employed to visualize lesions of the anterior cruciate ligament and the medial meniscus.

ing access to the interior of the joint cavity (Fig 265 C D) Through this capsular incision the anterior and the posterior cruciate ligaments and the medial meniscus are visualized and the degree of damage that they have suffered is determined The structures are disposed of in the following order the medial meniscus the anterior cruciate ligament the deep layer and, lastly the superficial layer of the tibial collateral ligament

If the medial meniscus is detached from the deep ligament and the capsule, or if it exhibits a tear in its substance it is excised in toto If the anterior cruciate is torn from



Fig 266 (A and B) A method of attachment of the tibial insertion of the anterior cruciate ligament

the tibia, it is restored to its anatomic position by the following procedure. Two drill holes are made obliquely through the medial condyle of the tibia, the drill holes pass upward backward and inward, beginning on the anteromedial surface of the tibia approximately 4 cm. below the tibial brim and issuing from the superior surface of the tibia through the raw area of the anterior spine from which the ligament has been avulsed (Fig 266) A mattress suture using stout silk or stainless steel wire, is passed through the free end of the ligament, the ends of the suture are passed through sepa

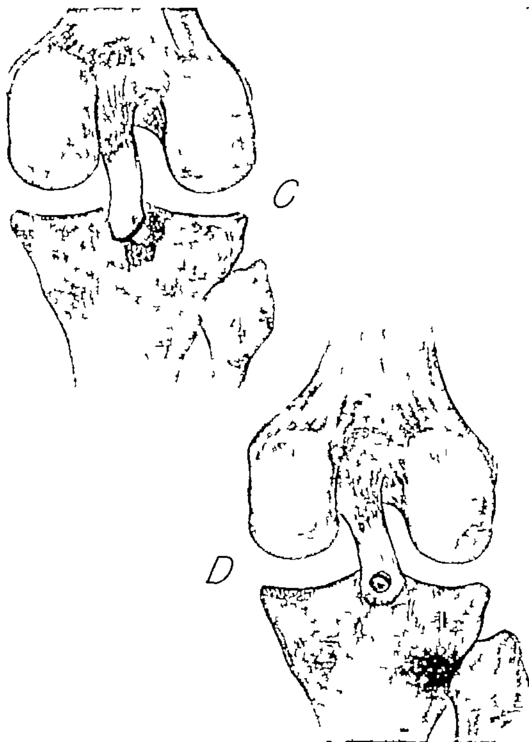


Fig 266 (C and D) A method of attachment of the tibial insertion of the anterior cruciate ligament

rate drill holes by a wire loop The ends are pulled tightly so that the ligament fits firmly in the raw bony bed and then tied In the event that the femoral attachment of the ligament is avulsed a similar procedure is executed (Fig 266 E F) A vertical skin incision 2 in in length is made on the lateral aspect of the femur immediately above the lateral epicondyle of the femur the incision is carried down to the bone and the periosteum is stripped off the bone for a short distance Two drill holes are made through the lateral femoral condyle they begin at the epicondylar ridge and pas

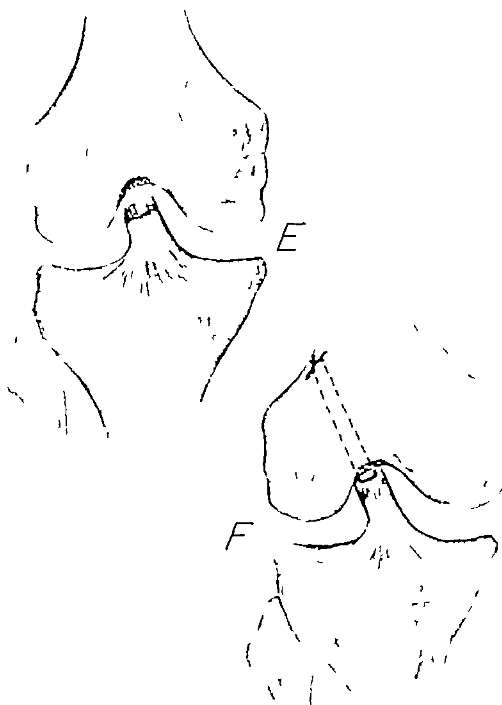


Fig 266 (E and F) A method of attachment of the femoral insertion of the anterior cruciate ligament

downward and inward they emerge in the intercondylar notch, the ligament is reattached to its anatomic position by the same method described for reattachment of the tibial insertion of the ligament (Fig 266 A B) If the ligament is shredded and elongated but its continuity remains intact, first the structure is imbricated and then its tibial attachment is pulled snugly onto a roughened area on the tibia by the same procedure employed to anchor a torn tibial attachment of the ligament

Tears of deep and superficial layers of the tibial collateral ligament are next repaired the method of repair in combined lesions is similar to that described for isolated lesions of the structure Finally, the capsule in front and behind the ligament is inspected carefully, and all defects are closed by interrupted sutures. Every attempt should be made to repair the implicated structures in such a fashion that their physical structure and their performance approach the normalcy The edges of the investing layer of fascia and the skin are approximated in separate layers by interruped cotton sutures

Postoperative Management At the termination of the operation the limb is enclosed in a well padded plaster cylinder extending from the groin to above the malleoli with the knee in full extension At the end of 3 weeks the cast is replaced by a snug fitting skintight plaster cylinder weight bearing is now permitted The total length of immobilization must be governed by the judgment of the surgeon who is familiar with the severity of the lesion and knows the effectiveness of the repair that he performed Generally from 6 to 8 weeks of immobilization will suffice

Quadriceps setting and loaded straight leg raising are commenced immediately after the removal of the first plaster cylinder more vigorous exercises are instituted which are designed to restore maximum power to the quadriceps and normal stability and motion to the knee joint If an effusion into the joint cavity should occur after the removal of the second plaster cylinder (6 to 8 weeks after operation), an elastic bandage may be worn around the knee It is of utmost importance to restrict unprotected weight bearing until the quadriceps has attained sufficient power to stabilize the knee joint adequately failure to understand the significance of this precaution can lead only to repeated effusions delay in the convalescent period and permanent laxity of the ligamentous extensor apparatus Exercises ever increasing in intensity may require from 4 to 6 months before optimum power is achieved by the extensor group of muscles

Conservative Management of Combined Lesions It was pointed out previously that conservative management is indicated in severe sprains of the tibial collateral ligament, in these cases the continuity of the ligament remains intact Occasionally, in combined lesions the presence of severe soft tissue damage, such as extensive abrasions and lacerations, precludes immediate surgical intervention Also in some cases with associated fractures of the lateral femoral condyles conservative measures suffice because in these instances the violence of the force is expended by the tibial condyles and the ligaments sustain only minor injuries

In cases exhibiting marked swelling, first the joint is aspirated and then a compression elastic bandage is applied over voluminous sheet cotton extending from mid thigh to mid-calf Further immobilization is provided by a long posterior plaster splint extending from the tuberosity of the ischium to above the malleoli it is fastened to the extended limb by elastic bandages Ice bags applied around the knee joint add to the comfort of the patient. The limb should rest on the bed without a pillow under the knee joint If bleeding into the joint cavity continues aspiration of the joint is repeated As a rule after 8 to 10 days the swelling subsides sufficiently to allow the application of a skintight plaster cylinder reaching

from the groin to above the malleoli The cast is applied directly over a single layer of stockinet or a single layer of elastic adhesive bandage (elastoplast) No exercises except quadriceps setting are executed before the plaster cylinder is applied After immobilization the patient is put on a regulated regimen of quadriceps exercises comprising first straight leg raising against elastic resistance and, later, exercises of the extensor apparatus in which the muscles work against progressively increasing loads. If no fractures of the tibial condyles are present weight bearing may be resumed after application of the plaster cylinder The length of the period of immobilization is governed by the severity of the injury to the ligamentous apparatus in the absence of fractures it varies between 6 and 8 weeks If a fracture exists weight-bearing is not allowed before 10 or 12 weeks however during this period exercises designed to restore normal power to the quadriceps are performed After the removal of the plaster some support may be provided by an elastic bandage Then exercises to restore normal flexion to the knee joint are added Conscientious performance of the exercises on the part of the patient and careful guidance on the part of the attending surgeon enhance rapid restoration of power and stability of the limb and shorten the period of rehabilitation

Case Report of an Incomplete Lesion of the Tibial Collateral Ligament.

Case A D a white male 20 years old sustained a twisting injury of the right knee while playing basketball Although he had considerable pain he was able to finish the game after the knee was strapped with adhesive tape He was seen the day following the injury

Physical examination of the limb disclosed considerable swelling particularly in the suprapatellar region The knee was held in 20 of flexion and the patient resisted any passive attempts to extend the knee There was considerable tenderness along the course of the entire tibial collateral ligament the area of maximum tenderness being at the tibial attachment Forceful abduction of the leg elicited severe tenderness on the inner aspect of the knee Further examination was conducted with the patient under intravenous Pentothal Sodium Now the limb could be fully extended aspiration of the joint yielded 60 cc. of blood No abnormal abduction rocking or abnormal motion of the tibia on the femur in the sagittal plane could be demonstrated Anteroposterior roentgenograms taken with the knees bound together and a sandbag wedged between the feet failed to show an increase of the inner joint space of the affected limb. A diagnosis of an incomplete tear of the tibial collateral ligament was made and conservative treatment, as outlined previously was instituted.

Examination of the patient 8 weeks later revealed a stable painless knee with normal function. The young man was ready to resume his athletic pursuits. This case presents the classic features of incomplete lesions of the tibial collateral ligament except for one feature namely the presence of a massive hemarthrosis The presence of blood in the joint cavity leads one to believe that a tear of the synovialis must have occurred at the time of the injury this premise was confirmed by the absence of injury to other ligaments however, a tear of the peripheral attachments of the meniscus must also be considered Failure of subsequent development of clinical features consistent with internal derangement of the knee joint eliminates this last possibility

Case Report of Complete Rupture of the Tibial Collateral Ligament (Isolated Lesion)

Case S F., a white male 17 years of age He was injured while playing football he was carrying the ball when suddenly he was "clipped from the outside by an opposing player He felt immediate excruciating pain in the left knee joint and had a feeling as if something snapped on the inner side of the joint He was unable to continue the game A diagnosis of a sprained ligament was made by a local physician and bed rest and cold packs were prescribed

Examination 3 days later revealed marked swelling of the knee joint which was held in slight flexion some local tissue swelling and ecchymosis were discernible on the inner aspect of the knee Pain and muscle spasm precluded any active or passive extension of the joint Digital pressure elicited tenderness along the course of the whole tibial collateral ligament the area of maximum tenderness

was located in the region of the femoral attachment of the ligament. Forceful abduction of the tibia produced severe pain on the inner aspect of the joint, the drawer sign was negative.

Next, the patient was examined under general anesthesia. Aspiration of the joint produced 45 cc. of blood In the extended position no abnormal lateral instability was demonstrated however, with the knee slightly flexed, marked abduction rocking was observed readily *A diagnosis* of a complete rupture of the ligament was made, and surgical repair was recommended Roentgenographic studies disclosed widening of the medial joint space on the injured side.

Exploration of the inner aspect of the knee disclosed a complete rupture of the femoral attachment of the superficial portion of the ligament a small stump of the ligament still remained attached to the femur In addition, the femoral origin of the deep layer, together with the capsule was avulsed from the bone and had retracted to the level of the joint line The meniscus and the anterior cruciate ligament were intact.

Repair of both layers of the ligament was effected as described previously Immobilization in a plaster cylinder was continued for 6 weeks. Four months later examination revealed a stable, painless joint with a normal range of motion The patient had resumed participation in all school athletic activities.

This case exemplifies an isolated lesion of the tibial collateral ligament in which both layers were ruptured completely Early and adequate repair of the affected structures ensured the patient a normal extremity

Case Reports of Combined Lesions.

Case I R., a white male 19 years old. While running across a football field he was "struck from behind" by one of his own teammates His left knee buckled and he fell to the ground the impact was accompanied by severe pain on the outer side of the knee joint, and the patient felt a sensation of "something tearing in the joint." He was unable to extend the knee. One of the trainers attempted to straighten the knee by steady traction but the knee remained in the flexed position.

He was examined about 6 hours after the



Fig 267 Roentgenograms of Case I R. showing wide separation of the medial joint space of the left knee joint. Such marked displacement could be produced only by a combined lesion of the tibial collateral ligaments and the anterior cruciate ligament. In this instance the anterior cruciate ligament was found detached from its femoral insertion

accident The knee was held in 20 of flexion and exhibited marked swelling particularly in the suprapatellar region Even without anesthesia considerable lateral rocking and a positive anterior drawer sign was demonstrable in the partially flexed joint. Pressure over the tibial collateral ligament elicited marked tenderness particularly in the region of the femoral attachment of the ligament Forceful abduction of the tibia on the femur accentuated the pain Roentgenographic studies with the flexed knees bound together and the lower legs wedged apart exhibited marked widening of the medial joint space on the affected side (Fig 267) A presumptive diagnosis was made of complete rupture of the tibial collateral and anterior cruciate ligaments and a displaced medial meniscus.

The operative findings confirmed the clinical diagnosis The superficial portion of the collateral ligament was avulsed from its femoral insertion leaving a raw bony surface the femoral attachment of the deep portion was also completely detached from its bony insertion and had been pulled in the joint space so that it lay like a curtain on the superior surface of the medial meniscus In addition the medial meniscus had sustained a complete bucket handle tear and its central portion was displaced into the intercondylar notch. The anterior cruciate ligament was avulsed from the femur and lay curled up on the intercondylar surface of the tibia.

Repair was achieved by excision of the torn meniscus next the torn anterior cruciate was reattached to its anatomic position through 2 drill holes in the lateral femoral condyle the deep portion of the ligament was fastened to its normal position by interrupted cotton sutures and the superficial portion of the ligament was anchored in a slot cut on the side of the femoral condyle Plaster fixation was maintained for 8 weeks.

Examination 4 months after operation disclosed slight atrophy of the quadriceps muscle with no lateral instability in extension but slight abduction rocking in flexion the anterior drawer sign was negative Ten months later the patient resumed his athletic pursuits at this time the volume and the power of the quadriceps was equal to that of the normal side no abnormal lateral instability was demonstrable with the knee in flexion



Fig 268 Roentgenograms of Case C K Note the widening of the medial joint space and the detachment of the femoral insertion of the tibial collateral ligament The ligament has pulled off a small fragment of bone from the epicondyle of the femur The fragment has been displaced distally *In this instance there was also a tear of the anterior cruciate ligament*

Case C K., a white male 46 years of age He was struck on the outer side of the knee by the front bumper of an automobile. One hour later he was admitted to the hospital Examination revealed some local swelling and discoloration on the outer aspect of the joint Some swelling in the parapatellar and the suprapatellar regions was discernible The knee could be extended readily to 180 Lateral rocking of the tibia on the femur with the femur fixed was demonstrable in both the extended and the flexed positions The anterior drawer sign was positive Digital pressure over the femoral attachment of the ligament elicited excruciating tenderness. Roentgenograms disclosed marked widening of the inner side of the medial joint space, also a small fragment of bone was seen detached from the medial surface of the femur (Fig 268) These findings permitted one to make a diagnosis of a complete rupture of both the tibial collateral ligament and the anterior cruciate ligament.

Exploration of the inner aspect of the knee revealed that the femoral attachment of the superficial portion of the tibial collateral ligament with a small piece of bone was avulsed from the medial surface of the femur By abducting the tibia a wide gap in the deep portion of the ligament was seen immediately above the upper border of the medial meniscus which was completely detached from its peripheral attachments and lay loosely in the joint. The anterior cruciate ligament was avulsed from its tibial attachment

In the repair of the implicated structures the medial meniscus was excised in toto The anterior cruciate was approximated to its area of insertion into the tibia by a suture passing through two drill holes in the inner tibial condyle. The two ends of the deep portion of the ligament were first imbricated and then sutured together the free fragment of bone still attached to the femoral end of the superficial portion of the ligament was excised and the end of the ligament was anchored in a slot cut out of the side of the inner surface of the medial condyle of the femur At the termination of the repair a plaster cylinder was applied with the knee extended 180 it was removed at the end of 3 weeks and another plaster cylinder was applied Total plaster immobilization was maintained for 8 weeks.

At the end of 6 months the patient had no abnormal abduction rocking with the knee in the extended or flexed position however he did have slight increased anterior displacement of the tibia on the femur in the sagittal plane (positive drawer sign) The quadriceps had achieved volume and power comparable with that of the normal side. He was able to perform all activities which he was capable of doing before the accident

Injuries of the Fibular Collateral Ligament

The anatomic location of the fibular collateral ligament renders it less vulnerable to injury than the medial ligament. The opposite limb protects it from adduction subluxating forces in addition it is strengthened by the iliotibial band the tendon of the biceps femoris muscle, the tendon of the popliteus muscle and the lateral head of the gastrocnemius muscle Because the structure is relaxed in all positions of flexion, it is rarely injured by rotary forces except in cases of severe subluxation or dislocation of the knee joint. The mechanism whereby the fibular collateral ligament is ruptured is usually one of forceful adduction of the leg on the femur Rarely is the lesion an isolated one usually concomitant lesions are produced by the above mechanism these comprise tearing of the lateral portion of the fibrous capsule and its synovial lining, fraying or severance of the popliteus tendon, the lateral head of the gastrocnemius and the iliotibial band and stretching or rupture of the common peroneal nerve The nerve lesion is the most important associated lesion because frequently it is followed by permanent paralysis resulting in loss of dorsiflexion of the foot Occasionally the cruciate ligaments are implicated

As noted previously the fibular collateral ligament is a stout cord of connective tissue fibers whose distal insertion is located in the head of the fibula. In most instances severe adduction forces result in rupture of the inferior attachment of the ligament often a fragment of bone is avulsed from the head of the fibula If the force is continued the deeper portion of the ligament, which blends with the capsule is ruptured at its middle in rare instances rupture of the ligament may be associated with an avulsion of a

piece of bone of the outer aspect of the lateral condyle of the femur

As noted above, the peroneal nerve may be stretched or torn in both types of lesions The prognosis is grave By early surgical intervention it may be possible to perform some type of repair to bring together the healthy ends of the nerve however, stretching and fraying of the nerves invariably indicates severe laceration of the nerve bundles and vascular impairment of a large segment of the nerve repair in these cases is difficult and often impossible

Clinical Features. In all instances there is a history of severe force to the inner aspect of the knee driving the tibia into varying degrees of adduction Pain is localized to the outer aspect of the joint Some local swelling is usually discernible in this region. In isolated lesions without injury to the intra articular structures or the synovialis no effusion or hemorrhage into the joint ensues However if rupture of the ligament is complicated by tearing of the capsule or cruciate ligaments varying degrees of swelling occurs Palpation along the course of the ligament invariably elicits maximum tenderness at the site of the lesion. In isolated lesions abnormal adduction rocking is demonstrable with the knee in the extended position however the drawer sign is negative Roentgenograms taken of both knees in the same position while forceful adduction is made on the tibiae reveal widening of the lateral joint space on the affected side

Combined lesions exhibit clinical manifestations which point to the true nature of the pathology present Rupture of the deep portions of the ligament and of the fibrous capsule results in hemorrhage into the joint. This also occurs when the cruciate ligaments are traumatized If a rupture of the anterior cruciate ligament exists the drawer sign is positive and adduction rocking is increased considerably, both in extension and flexion Implication of the common peroneal nerve is evident by both sensory motor manifestations Complete paralysis of the muscles supplied by the nerve distal to the injury produces a "drop foot"

Treatment. Both isolated ruptures and combined lesions of the fibular collateral ligament should be explored first and evaluated by direct visualization of the pathology present and then repaired by surgical me

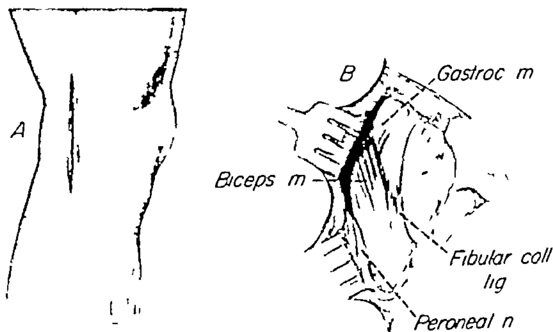


Fig 269 Method of exposure of the fibular collateral ligament

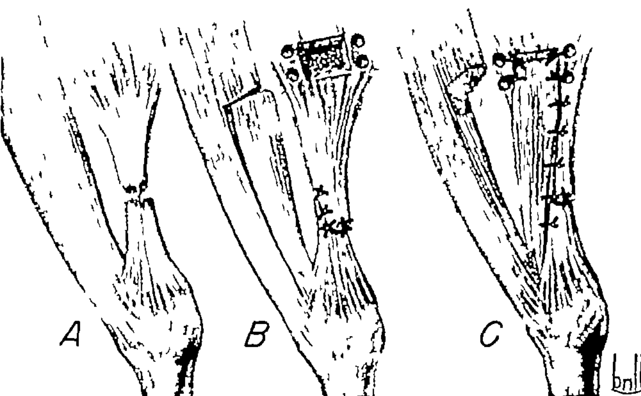


FIG 270 (A and B) Repair of the fibular collateral ligament by utilizing a segment of the tendon of the biceps femoris muscle. (C) Note that the tendon is attached to the remaining portions of the external fibular lateral ligament

ods (Fig 269) Generally, the ends of the torn ligament and the edges of the gap in the capsule can be approximated and even imbricated by interrupted cotton sutures In the event that the anterior or the posterior cruciate ligaments are ruptured repair is effected in the same manner as that described previously The superficial and the deep (capsular) portions of the ligament should be repaired separately, in addition, the author reinforces the ligament by utilizing a segment from the tendon of the biceps femoris muscle This should be sufficiently long to reach the femoral attachment of the fibular collateral ligament it is left attached to the neck of the fibula, and its proximal end is anchored in a slot made on the lateral aspect of the lateral femoral condyle. Then the new ligament is fastened to the fibular collateral ligament by interrupted sutures (Fig 270) If fragments of bone have been detached from the head of the fibula or the lateral margin of the tibia, they may be either replaced in their original site or excised, depending upon their size The methods of reattachment of the ruptured distal end of the ligament are depicted in Figure 271

In all instances the external popliteal nerve should be explored Early and meticulous repair of a ruptured nerve provides a better chance of recovery than late repairs At best traction lesions of the type encountered with tears of the fibular collateral ligament are difficult to repair and, as noted previously, the prognosis is poor

Postoperative Management. This phase of the treatment is similar to the postoperative management following repair of ruptures of the tibial collateral ligament In the event that a repair of the external peroneal nerve has been performed, after the cast is removed the patient is fitted with a brace having a drop foot stop Elec

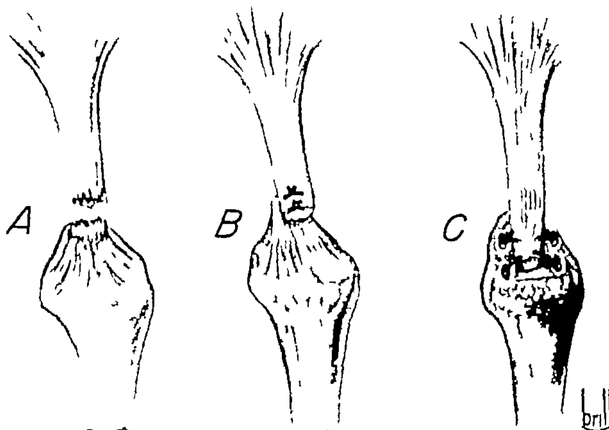


FIG 271 Methods of reattachment of the ruptured distal end of the fibular collateral ligament. (A) Suture of the fibular ligament (B) Reattachment of the severed ends of the ligament by interrupted sutures (C) Method of anchorage of the detached end of the ligament into a slot made in the head of the fibula

trical stimulation of the paralyzed muscles should be employed to maintain tone and volume If after repair of the nerve and the lapse of a reasonable period of time it becomes apparent that the paralysis is permanent then some type of operation on the ankle joint must be contemplated in order to hold the foot in the desired position in relation to the tibia such as arthrodesis of the ankle joint or a posterior bone block

The following case represents a typical example of complete rupture of the fibular collateral ligament

Case R I a white male 19 years of age While playing football he was struck on the inner side of the left knee by a blocker of the opposing team He experienced immediate pain on the outer aspect of the joint however he continued to play ball until the end of the period His knee was strapped by the trainer and cold packs were applied to the outer aspect of the joint he was seen the following day in the hospital

Examination at this time disclosed considerable swelling of the entire knee joint and some local swelling over the outer aspect of the knee The limb was held in slight flexion the patient resisted any attempt to extend the knee The joint was aspirated and 30 cc of blood tinged fluid was obtained Palpation *elicited maximum tenderness over the inferior* attachment of the ligament this area was infiltrated with 5 cc. of procaine Then extension of the knee was possible Abnormal adduction rocking was readily demonstrable *with the knee in extension Roentgenograms* revealed widening of the outer joint space the drawer sign was negative with no neurologic manifestations implicating the external popliteal nerve

Immediate exploration of the fibular collateral ligament disclosed complete rupture of its inferior attachment close to the head of the fibula Also a transverse tear of the deep fibers of the ligament and of the fibrous cap-

sule at the level of the middle of the joint space was demonstrable, adduction rocking opened up the defect in the capsule so that the popliteus tendon came into view, this structure and the external meniscus were intact The external popliteal nerve was explored and found to be undamaged.

Repair was achieved by closure of the defect in the capsule and deep portion of the ligament by interrupted cotton sutures the inferior end of the superficial portion of the ligament was reattached to the head of the fibula. The entire structure was reinforced by a segment from the tendon of the biceps femoris muscle by the method described previously A plaster cylinder was applied holding the knee extended and abducted the cylinder was worn for 6 weeks, and the usual postoperative regimen to restore normal quadriceps power was instituted This patient resumed his position on the football squad the following season.

RECENT INJURIES OF THE ANTERIOR CRUCIATE LIGAMENT

The important role of the anterior cruciate ligament in the functional mechanics of the knee joint has been stressed in Chapter 5 It was pointed out that this structure not only helps to stabilize the joint in both the extended and flexed positions by preventing abnormal motion in the lateral and the sagittal planes but it also guides the path of motion of the lateral femoral condyle *in relation to the tibia* Also *together* with certain other supporting structures (particularly the capsule the medial collateral ligament and the posterior cruciate ligament) it governs the arc of rotation of the tibia on the fixed femur in both extension and flexion Finally it is one of the factors controlling both hyperextension and hyperflexion. As pointed out by Goodsir and re-emphasized by Smillie, one of the chief functions of this structure is control of outward rotation of the tibia in the last few degrees of extension which comprises the screw home movement. Derangement of this mechanism results in the production of the more common lesions of the anterior cruciate ligament



FIG 272 (*Left*) Avulsion of the anterior cruciate ligament, together with the anterior tibial spine. Displacement is minimal hence, treated by conservative measures. (*Right*) Roentgenogram taken 8 weeks later showing healing at fracture site The knee is stable.

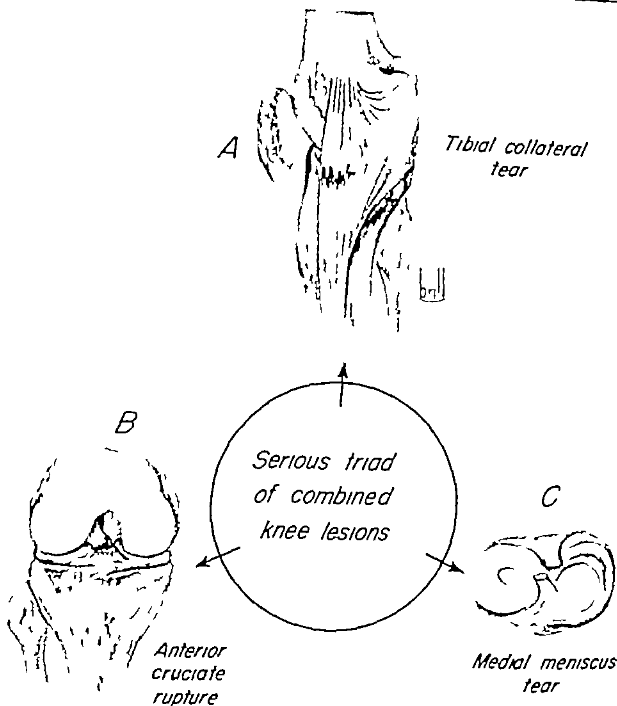


FIG 273 Diagrammatic representation of the triad of lesions frequently encountered following injuries forcing the knee into abduction and flexion while the femur is rotated medially on the fixed tibia

Mechanism of Injury of the Anterior Cruciate Ligament

Isolated Lesions. These lesions are encountered less frequently than lesions of the anterior cruciate ligament complicated by associated ligamentous or meniscal damage They occur in one of several forms the ligament may be avulsed together with a fragment of bone from the upper surface of the tibia this lesion is comparable with a fracture of the tibial spine (Fig 272) the superior attachment may be avulsed from the lateral femoral condyle or one or both ends may be partially ruptured but some

bers of the ligament retain continuity of ye structure This may occur within the ynovial sheath of the ligament, so that the ructure may appear to be stretched or at enuated Generally, the above lesions are roduced by violent hyperextension of the nee joint or a direct blow on the anterior urface of the femur with the knee flexed riving it backward while the tibia is fixed n young individuals, particularly in the dolescent period, avulsion of a portion of ye tibial spine with the ligament attached s observed more frequently than the other wo types of lesions mentioned (Fig 257)

Combined Lesions. These lesions are sually the result of abnormal rotary forces r forceful abduction of the tibia It was ointed out in the study of the mechanics f the knee joint (Chap 5) that the entire ibial collateral ligament is taut in exten ion also that during the entire phase of exion some of the long anterior fibers re main taut. Hence it becomes apparent that he integrity of the anterior cruciate be as-ured so long as the tibial collateral liga ment remains intact However rupture of he tibial collateral ligament makes the an erior cruciate ligament vulnerable, and if he abduction force continues rupture or tretching of the cruciate ligament ensues The abduction mechanism is responsible for he most serious type of injury of the knee oint, because it usually results in rupture of both the tibial collateral and the anterior ruciate ligaments a combination which is accompanied invariably by severe dysfunc tion of the knee joint. This same mecha nism may produce rupture of the tibial col lateral and the anterior cruciate ligaments and also a fracture of the lateral condyle of the tibia. As noted in the discussion of lesions associated with complete rupture of the tibial collateral ligament, the most fre quent triad produced by abduction flexion and medial rotation of the femur on the tibia is rupture of the tibial collateral liga ment, rupture of the anterior cruciate liga ment and tearing of one of the menisci as a rule the medial meniscus (Fig 273)

Rotation mechanism may result in tears of both the medial meniscus and the an terior cruciate ligament at the time of the initial incident. On the other hand, as pointed out by Smillie, the mechanism may result in a longitudinal tear of the meniscus without involvement of the cruciate liga ment, however, if the torn displaced menis-cus produces a permanent mechanical block to normal lateral rotation of the tibia when the knee is extended, forced extension of the joint tends to stretch and eventually rupture the anterior cruciate ligament If the ob-struction to lateral rotation of the tibia re sults suddenly by a displaced central seg ment of the torn medial meniscus and at the same moment the knee is extended forcefully such as may occur on the foot ball field acute rupture of the anterior cruciate ligament may ensue It becomes obvious that repeated incidences of locking cause gradual stretching and eventually rupture of the anterior cruciate ligament also weight bearing on a truly locked knee joint produces the same result This pro-vides an explanation for the high incidence of attenuated or ruptured anterior cruciate ligaments encountered in cases with lesions of a menisci which are capable of producing recurrent episodes of locking the medial meniscus is implicated more often than the lateral

Clinical Features

Isolated Lesions. Uncomplicated rup-tures of the anterior cruciate ligament are exceedingly rare, however, they do occur and the mechanisms producing the lesions have been recorded the most common type is forcible hyperextension of the joint The lesions as noted previously are encountered more frequently in young individuals, par ticularly in the adolescent period of life In all instances there exists a history of some form of violence to the knee joint. Rupture of the ligament or avulsion of a portion of the upper surface of the tibia invariably is

accompanied by hemorrhage and synovial effusion into the joint cavity. At the time of the accident the patient frequently experiences a sensation of something tearing within the joint and immediately thereafter he is aware of a feeling of instability in the knee joint on weight bearing when the knee moves into a position of flexion. Large amounts of blood and synovial effusion may distend the joint markedly; this is followed invariably by pain, reflex spasm of the hamstrings holding the joint in varying degrees of flexion and restriction of normal flexion and extension of the joint.

In the presence of the aforementioned features it becomes apparent that adequate examination of the part becomes difficult and at times impossible unless the intra-articular tension is reduced by aspiration of the blood and the synovial effusion. At times, even after aspiration of the joint, satisfactory examination is not possible. In these cases it is justifiable to administer a general anesthetic agent, preferably Pentothal Sodium, in order to diminish pain and abolish the reflex spasm of the hamstring muscles.

The most important single clinical feature always present when dissolution of the continuity of the anterior cruciate ligament has occurred is the positive anterior "drawer sign." If the patient is examined immediately after the injury before the joint cavity becomes distended with blood and synovial fluid, it may be possible to elicit the abnormal forward gliding of the tibia on the fixed femur. In most instances the patient is rarely available for examination at this time; hence the aspiration of the joint and a general anesthetic become imperative if an accurate evaluation of the existing lesion is to be made.

The maneuvers comprising the "drawer sign" demonstrate the presence or the absence of abnormal forward or backward displacement of the tibia on the fixed femur in the sagittal plane; the test is performed with the knee flexed 90° (Fig. 261 B). Dissolution of the continuity of the anterior cruciate ligament permits abnormal forward gliding (positive anterior drawer sign) of the tibia, while rupture of the posterior cruciate allows abnormal backward glidin (positive posterior drawer sign). There is present some anteroposterior motion in the normal joint; therefore, the unaffected knee always should be tested in order to estimate what is the normal amount of motion for the patient. In the absence of a concomitant lesion, rupture of the anterior ligament permits only a minimal amount of abnormal forward gliding of the tibia. If the tibial collateral ligament is stretched or ruptured, the amount of displacement is increased considerably, and if a rotary element is added to the maneuver the displacement is maximal.

Roentgenographic studies should be made of all cases; however, the findings are of significance only when a sprain fracture of the tibial spine or a fracture of the lateral tibial plateau are visualized.

Combined Lesions (Of the Medial Meniscus and the Anterior Cruciate Ligament). The medial meniscus and the anterior cruciate ligament may be torn by the same mechanism at the time of the original accident, which as a rule is produced by a violent rotation mechanism, usually on the football field. As pointed out by Smillie, in the event that the meniscus alone is torn and the tear is of such a nature that it is capable of locking the joint, the anterior cruciate is vulnerable to injury. With each episode of locking any attempt to extend the joint stretches the anterior cruciate ligament because the displaced meniscus prevents normal external rotation of the tibia on the femur. If these incidents are repeated, the attenuated ligament eventually ruptures. Such findings are observed frequently in knee joints with old meniscus tears which caused recurrent locking and finally come to surgery (Fig. 274).

It is often difficult to make a correct diagnosis when both lesions are produce

by the same injury mechanism If locking of the joint occurs, the lesion of the anterior cruciate ligament may be overlooked However, in the event of a hemarthrosis, injury of the anterior cruciate ligament must be suspected and a careful examination should be made to establish or eliminate the presence of the lesion One must bear in mind that hemarthrosis may also be the result of laceration of the synovial lining tearing of the peripheral attachment of the meniscus from the capsule or a fracture of the tibial spine or the tibial plateau If a definite mechanical block to extension exists and it can be established that the obstruction is not the result of a displaced fragment of the tibial spine one must assume that the meniscus is torn and a segment of the structure is displaced into the center of the joint, causing the locking In the event that locking is not present at the time of examination, it is difficult to determine the presence of a meniscal lesion. Stretching or tearing of the anterior cruciate ligament is established by a positive drawer sign. As in isolated lesions, an adequate examination can be performed only when the muscles about the joint particularly the hamstrings are completely relaxed and the joint cavity has been evacuated of blood and synovial fluid This may entail repeated aspirations and a general anesthetic agent Roentgenographic studies are essential to determine the presence or the absence of a fracture of the tibial spine or the tibial surface

Combined Lesions (Of the Anterior Cruciate Ligament, the Tibial Collateral Ligament and One of the Menisci) This triad has been considered in the discussion



Fig 274 This patient discloses forward displacement of the tibia on the fixed femur with the knee at right angles. In this case 2 lesions were found a longitudinal tear of the medial meniscus and the complete destruction of the anterior cruciate ligament. This figure depicts the amount of anterior displacement of the tibia present 6 months after meniscectomy This patient was able to do ordinary activities however he was unable to participate in any athletic pursuits (*Left*) The flexed knee before forward traction is made on the tibia (*Right*) Forward traction on the tibia produces a positive drawer sign indicative of a torn anterior cruciate ligament.

dealing with lesions associated with a complete rupture of the tibial collateral ligament

Management of Lesions

Considerable controversy exists relative to the advisability of surgical repair of a torn anterior cruciate ligament when it exists as a single lesion. It is common knowledge that a knee with a ruptured anterior cruciate ligament and a powerful extensor apparatus is capable of meeting the ordinary demands of function however it is not capable of performing arduous activity such as is needed on a football field It is the author's opinion that if no contraindications exist every attempt should be made to restore the joint to normalcy The operative procedures entailed should not be deterring factors This is particularly true when the lesion is encountered in young athletically inclined individuals

Two varieties of ruptures of the anterior cruciate ligament lend themselves admirably to repair These are avulsion of a portion of the tibial spine to which the inferior end of the ligament is attached and rupture of the superior attachment of the ligament Cases in which the ligament is stretched frayed and attenuated are more difficult to repair and sometimes the laceration of the ligament is so extensive that repair is impossible

Avulsion of a Portion of the Tibial Spine The choice of treatment is governed by the degree of displacement and in the event of displacement, whether or not the fragment can be perfectly restored to its normal anatomic position Occasionally a sprain fracture is observed without displacement in such instances the ligament retains its normal length and surgical intervention is not justified (Fig 272) Such cases can be treated by conservative methods First the joint cavity is aspirated re

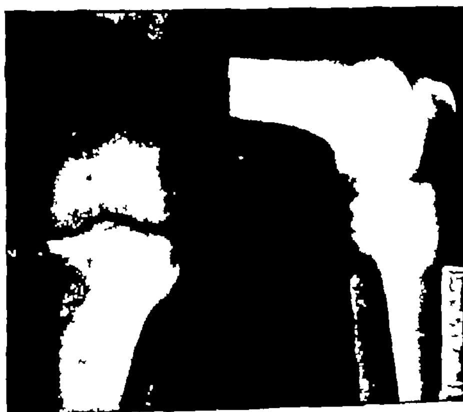


Fig. 275 Note a fracture of the tibial spine with displacement into the intercondylar notch of the femur This patient was treated by operative measures as depicted in Figure 266 A B

moving as much blood and synovial fluid as is attainable, then a nonpadded plaster cylinder with the knee in extension is applied If the detached fragment of bone is relatively large, including a portion of one of the tibial plateaus, it may be possible to restore the bone to its normal site by hyperextension of the knee joint. By this maneuver the femoral condyle will make pressure on the large bone fragment and force it into its normal position If roentgenograms reveal that when the joint is brought to the neutral position (180° extension) no redisplacement of the fragment occurs, a nonpadded plaster cylinder is applied from above the malleoli to the groin immobilizing the limb in 180° extension at the knee joint. Before reduction is attempted the patient is given a general anesthetic, and the joint is evacuated of blood and synovial fluid by aspiration No weight bearing is allowed for a period of 3 weeks at the termination of this period the plaster cylinder is removed, and another cylinder is applied now weight bearing is allowed. Quadriceps exercises are performed during the entire period of immobilization. At the end of 6 to 8 weeks the cast is removed, and measures are instituted to restore joint function In the event that perfect reposition of the fragment is not achieved or the detached fragment is too small to be replaced by manipulation, surgical intervention is indicated (Fig 275)

Operative Technic In all instances a tourniquet is applied around the upper third of the thigh A medial parapatellar incision is employed to expose the intercondyler region of the tibia. In recent lesions upon incising the synovial membrane large quantities of blood and synovial fluid may be encountered this is aspirated from the joint cavity The fragment is identified and the defect in the upper surface of the tibia is prepared to receive the fragment by curetting out organized blood clots and loose strands of tissue The fragment must fit perfectly in its bed otherwise the ligament will not be restored to its normal length. Occasionally, it may be necessary to deepen the defect by removing some of the bone with a curet or a gouge This allows the detached fragment to sit deeply in its bed, thereby taking all slack out of the ligament. This step is especially desirable in neglected cases in which sufficient time has elapsed since the accident to allow the formation of callus or even bone in the defect In such an event it becomes apparent that the original defect in the tibia becomes shallow or even obliterated and must be deepened in order to receive the detached fragment of bone

About 4 cm below the brim of the articular surface of the tibial condyle two parallel drill holes 1 cm apart are made in the medial condyle of the tibia. They begin on the anteromedial surface and are directed upward and inward, their exit is in the base of the defect located in the intercondylar region of the tibia If the fragment is large it is perforated by two small holes A stout silk or stainless steel suture is passed through the holes in the bone fragment then the ends of the suture are passed from within outward through the holes in the medial tibial condyle This last step is facilitated by the use of a wire loop which guides the ends of the suture to the outer surface of the tibia If the fragment is small the suture is passed through the inferior end of the anterior cruciate ligament close to the surface of the detached bone By pulling on the ends of the suture the fragment is seated snugly in its bed then the ends are tied over the intervening bone. The wound is closed in layers in the usual manner (Fig 266 A, B)

After the knee is wrapped in several layers of sheet cotton uniform compression is made with an elastic bandage The compression dressing extends from the middle of the calf to mid-thigh. At this point the tourniquet is removed The limb is immobilized on a posterior plaster splint, extending from the ankle to the upper region of the thigh

As a rule within 10 to 14 days the post

operative reaction will have subsided sufficiently to allow the application of a nonpadded plaster cylinder extending from above the malleoli to the groin. Weight bearing is allowed from 3 to 4 weeks after operation; however, quadriceps exercises are commenced immediately after the cast is applied. Plaster immobilization is continued for 6 to 8 weeks; after the plaster cylinder is removed, exercises are instituted on a regulated regimen designed to restore normal power to the extensor mechanism and complete joint function.

Dissolution of the Anterior Cruciate Ligament Without Fracture of the Tibial Spine. This is an exceedingly rare lesion; the author never has encountered one except in combination with rupture of the tibial collateral ligament and tearing of one of the menisci or associated with a tear of one of the menisci alone. In the event that the lesion is encountered and recognized, it should be repaired, particularly in young individuals who are athletically inclined.

Operative Technic (Fig. 266 E, F). The joint is exposed through a medial parapatellar incision, and a stout silk or stainless steel suture is passed through the proximal end of the anterior cruciate ligament. A vertical incision 2 inches long is made on the lateral aspect of the femur immediately above the epicondyle of the lateral condyle of the femur. Two parallel drill holes 1 cm. apart are made in the condyle; they are directed downward and inward so that their exit lies in the area of the inner surface of the condyle which normally provides attachment of the superior end of the ligament. The two ends of the suture previously passed through the ligament are drawn through the drill holes from within outward using a wire loop; the ends are made taut and then tied over the intervening bone, thereby pulling the detached end of the ligament snugly against its normal site of insertion.

The postoperative management is similar to that described for detachment of the inferior end of the anterior cruciate ligament.

Rupture of the Anterior Cruciate Ligament Associated With a Tear of the Medial Meniscus. When this combined lesion is observed shortly after the accident, the choice of management comprises excision of the medial meniscus in toto and restoration of the normal anatomy of the anterior cruciate ligament. The ligamentous lesion is either a rupture of the femoral attachment or a sprain fracture of the tibial spine. Repair in each case is effected by the operative technics described previously (Fig. 266).

Postoperative management, however, differs from that of a simple meniscectomy. At the termination of the operation a compression elastic bandage is applied extending from mid-calf to mid-thigh. Quadriceps exercises are commenced at once. No weight bearing is permitted for 3 weeks; at the end of this period a plaster cylinder is applied, holding the limb in the extended position (180°). Weight bearing is now permitted. The plaster cylinder is removed approximately 6 to 8 weeks after the operation. The period of total fixation is governed by the judgment of the surgeon, who knows the severity of the lesion and the type of repair that he effected.

Although every effort should be made to restore the normal anatomy of the anterior cruciate ligament, particularly in fresh lesions occurring in young individuals, frequently during the course of a meniscectomy a torn or attenuated ligament is encountered in which a satisfactory repair cannot be effected. Such lesions usually comprise rupture of the femoral attachment of the ligament or severe stretching, fraying and elongation of the entire structure, its continuity being maintained by the synovial sheath. In these cases no attempt is made to achieve anatomic restoration of the ligament; after the involved meniscus is excised, a concerted effort is made to

redevelop the extensor apparatus to its maximum level of efficiency in order to compensate for the loss of the stability resulting from a defective ligament If a sprain fracture of a portion of the tibial spine with the inferior attachment of the ligament intact is encountered every effort should be made to replace the fragment in its normal anatomic position and restore the function of the ligament.

Other Combined Lesions Rupture of the anterior cruciate ligament associated with a tear of one of the menisci and dissolution of the tibial collateral ligament or associated with lesions of the medial ligament alone are considered in the section dealing with associated lesions of rupture of the medial ligament.

RUPTURE OF THE POSTERIOR CRUCIATE LIGAMENT

Isolated lesions of this structure are relatively rare and usually are the result of direct force driving the tibia posteriorly while the foot and the femur are fixed and the knee is flexed This mechanism is observed frequently when in an automobile accident the occupant of the front seat is suddenly thrust forward, striking one of the tibiae against the dashboard Two varieties of ruptures of the ligament are observed (1) a sprain fracture of the posterior portion of the upper end of the tibia the distal end of the ligament retains its attachment to the avulsed fragment and (2) a rupture of the femoral attachment of the ligament (Fig 258)

Clinical Features

The pertinent clinical manifestations are a history of severe violence driving the tibia backward while the knee is flexed an extensive hemarthrosis and a positive posterior drawer sign Immediately after the injury there is considerable dysfunction and the knee tends to "buckle when weight is borne on the flexed joint Generally, the knee joint is markedly distended with blood and synovial fluid In cases with avulsion of a fragment of bone from the upper surface of the tibia the posterior capsule may be ruptured, allowing extravasation of blood into the popliteal fossa, pressure in the popliteal space elicits severe tenderness Before spasm of the muscles crossing the knee joint occurs, the posterior drawer sign can be elicited readily, later, pain and spasm precludes a satisfactory demonstration of the backward mobility of the tibia on the femur Roentgenographic studies are of significance only when a detached fragment of bone is demonstrable In the absence of positive roentgenographic findings an adequate examination is possible only after the joint cavity is evacuated of blood and synovial fluid and the patient is relaxed completely by a general anesthetic. In addition to the mechanism described, rupture of the posterior cruciate ligament may be an associated lesion of total disruption of the ligamentous apparatus encountered in dislocation of the knee joint

Management

As in recent lesions of the anterior cruciate ligament ruptures of the posterior ligament should be repaired as soon after the accident as circumstances permit. In cases of avulsion of a portion of the superoposterior surface of the tibia, the detached fragment should be restored to its anatomic position

Operative Technic (Fig 276) The fracture site is exposed through a vertical "S" shaped incision centered over the posterior joint line After the lateral head of the gastrocnemius muscle is divided it is displaced medially together with the neurovascular structures in the popliteal fossa The posterior portion of the capsule now comes into view If a defect in the structure is present, it is visualized readily by hyperextending the knee joint The loose fragment is identified, and the site on the tibia

from which it was avulsed is curetted free of blood clots and other tissue debris

In the event that the fragment is relatively large it may be anchored to its normal position in the tibia by a screw, or occasionally it may be held in place by interrupted cotton sutures fastening it to the surrounding capsular tissue The writer prefers the former technic when it can be executed If the fragment is too small to hold a screw, or if it cannot be stitched securely to the surrounding tissues, a stout silk or stainless steel suture is passed through the end of the ligament and the

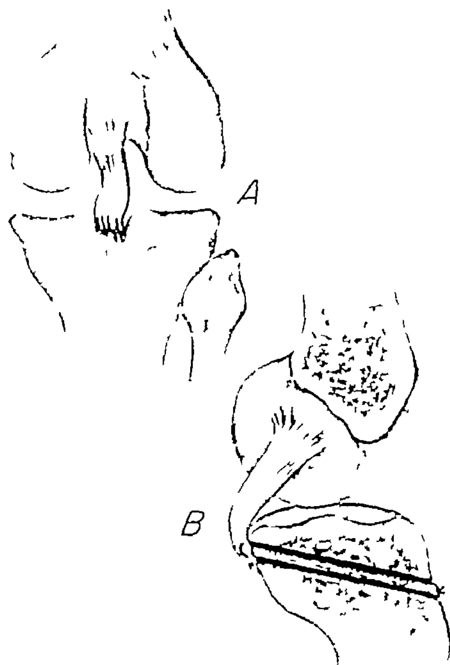


FIG 276 Methods of repair of lesions of the posterior cruciate ligament (A) Torn tibial attachment of the ligament (B) Reattachment of the ligament by a suture passed through the ligament and the ends passed through drill holes in the medial tibial condyle

ends are passed through parallel drill holes, 1 cm. apart, from within outward, which were made previously through the medial tibial condyle, beginning on its anteromedial surface 2 inches below the articular surface, a wire loop is employed to guide the ends of the suture through the holes then the ends are tied tightly on the intervening bone After the ends are tied the inferior end of the ligament should fit snugly in its normal anatomic position on the tibia (Fig 276 A, B) The author has employed the last procedure in only two cases, as a rule, the end of the ligament can be made secure to the surrounding capsular tissue

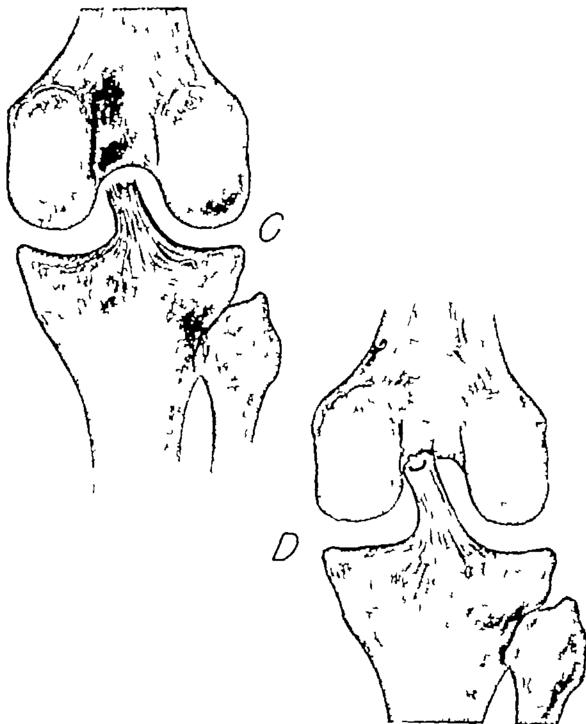


Fig 276 (C) Rupture of the femoral attachment of the posterior crucalte ligament. (D) Reattachment of the ligament by a suture passing through the ligament and the ends of the suture passing through drill holes in the medial femoral condyle

Repair of rupture of the femoral attachment of the ligament is effected with little difficulty because the ligament can be approximated readily to its normal site of insertion The same posterior incision as mentioned above is utilized to expose the structure A silk or wire suture is passed through the distal stump of the ligament and the ends are drawn from within out through two parallel drill holes previously made in the medial condyle of the femur The holes are drilled from immediately above the medial epicondyle to the area of attachment of the ligament on the lateral aspect of the condyle

After closure of the wound, a compression elastic bandage is applied and the limb is immobilized in a posterior plaster splint extending from the ankle to the groin and holding the knee flexed about 15 or 20° Quadriceps setting and drill are commenced immediately At the end of 10 to 14 days a nonpadded plaster cylinder is applied from above the malleoli to the groin now the leg is placed in 180° extension Weight bearing is allowed 3 or 4 weeks after the operation plaster immobilization is maintained for 6 to 8 weeks

In the event that roentgenograms reveal a sprain fracture of a portion of the superoposterior surface of the tibia but no displacement of the fragment is present operative intervention is not indicated First the knee is evacuated of blood by aspiration and then a plaster cylinder is applied The treatment is similar to that described for sprain fractures of the anterior segment of the tibial spine consistent with a rupture of the anterior cruciate ligament

PELLEGRINI STIEDA DISEASE (PARA ARTICULAR CALCIFICATION AND OSSIFICATION OF THE KNEE JOINT)

This entity is characterized by the formation of discrete calcareous deposits or bone adjacent to the adductor tubercle of the femur Generally the deposits are disk shaped conforming to the external surface of the medial condyle of the femur they vary in size and exhibit a constant pattern of development from the formative to the stage of maturity Since the report of Pellegrini in 1905 and that of Stieda in 1908 numerous cases have been recorded in the literature There still exists considerable controversy relative to the etiology and the pathogenesis of the lesion In spite of this disagreement the disorder pursues a course which is punctuated by specific pertinent clinical manifestations and pathognomonic roentgenographic findings, rendering the lesion readily recognizable

Etiology and Pathogenesis

Of the numerous etiologic factors which have been conceived as the agents responsible for this disorder trauma is the most likely cause It may be in the form of direct violence to the medial aspect of the knee or in the form of indirect forces resulting from severe rotary and abduction strains that implicate the upper attachment of the tibial collateral ligament Some of the other theories are avulsion of a piece of bone or periosteum from the adductor tubercle and injury to the bursa located immediately over the tubercle Also Nachlas and Olpp recorded that a membrane lines the fascia and invests the medial femoral condyle this membrane glides back and forth over the tubercle during normal joint motion Friction between the tubercle and the membrane produces degeneration and necrosis in the tissues this in turn forms the basis for the subsequent calcification and ossification characteristic of the disease As noted previously the evidence at hand indicates that the lesion is the result of injury to the femoral attachment of the tibial collateral ligament produced by direct or indirect violence As in myositis ossificans the resulting tissue damage is accompanied by extravasation of tissue fluids blood and death of connective tissue cell all of which form the basis for the development of cal



Fig 277 Note the elongated calcareous amorphous deposit in the substance of the medial longitudinal ligament in the region of the medial femoral condyle Note further that there is a definite interval between the deposit and the surface of the femoral condyle

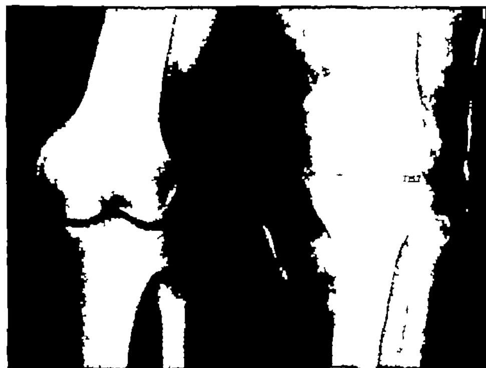


Fig 278 (*Left*) Note the formation of heterotopic bone in the region of the epicondyle of the femur and also some irregular amorphous deposits of calcium at the level of the joint space. The ossified ligament is attached to the epicondyle of the femur At this time the patient was having considerable pain, and the process was still in an active state (*Right*) Depicts the amount of bone and calcerous material excised from the substance of the ligament. Although this patient showed considerable improvement, some residual limitation of flexion was apparent.

Repair of rupture of the femoral attachment of the ligament is effected with little difficulty because the ligament can be approximated readily to its normal site of insertion. The same posterior incision as mentioned above is utilized to expose the structure. A silk or wire suture is passed through the distal stump of the ligament and the ends are drawn from within out through two parallel drill holes previously made in the medial condyle of the femur. The holes are drilled from immediately above the medial epicondyle to the area of attachment of the ligament on the lateral aspect of the condyle.

After closure of the wound, a compression elastic bandage is applied and the limb is immobilized in a posterior plaster splint extending from the ankle to the groin and holding the knee flexed about 15° or 20°. Quadriceps setting and drill are commenced immediately. At the end of 10 to 14 days a nonpadded plaster cylinder is applied from above the malleoli to the groin; now the leg is placed in 180° extension. Weight bearing is allowed 3 or 4 weeks after the operation; plaster immobilization is maintained for 6 to 8 weeks.

In the event that roentgenograms reveal a sprain fracture of a portion of the superoposterior surface of the tibia but no displacement of the fragment is present, operative intervention is not indicated. First, the knee is evacuated of blood by aspiration and then a plaster cylinder is applied. The treatment is similar to that described for sprain fractures of the anterior segment of the tibial spine consistent with a rupture of the anterior cruciate ligament.

PELLEGRINI-STIEDA DISEASE (PARA-ARTICULAR CALCIFICATION AND OSSIFICATION OF THE KNEE JOINT)

This entity is characterized by the formation of discrete calcareous deposits or bone adjacent to the adductor tubercle of the femur. Generally the deposits are disk-shaped, conforming to the external surface of the medial condyle of the femur; they vary in size and exhibit a constant pattern of development from the formative to the stage of maturity. Since the report of Pellegrini in 1905 and that of Stieda in 1908 numerous cases have been recorded in the literature. There still exists considerable controversy relative to the etiology and the pathogenesis of the lesion. In spite of this disagreement, the disorder pursues a course which is punctuated by specific pertinent clinical manifestations and pathognomonic roentgenographic findings, rendering the lesion readily recognizable.

Etiology and Pathogenesis

Of the numerous etiologic factors which have been conceived as the agents responsible for this disorder, trauma is the most likely cause. It may be in the form of direct violence to the medial aspect of the knee or in the form of indirect forces resulting from severe rotary and abduction strains that implicate the upper attachment of the tibial collateral ligament. Some of the other theories are avulsion of a piece of bone or periosteum from the adductor tubercle and injury to the bursa located immediately over the tubercle. Also Nachlas and Olpp recorded that a membrane lines the fascia and invests the medial femoral condyle; this membrane glides back and forth over the tubercle during normal joint motion. Friction between the tubercle and the membrane produces degeneration and necrosis in the tissues; this in turn forms the basis for the subsequent calcification and ossification characteristic of the disease. As noted previously, the evidence at hand indicates that the lesion is the result of injury to the femoral attachment of the tibial collateral ligament produced by direct or indirect violence. As in myositis ossificans the resulting tissue damage is accompanied by extravasation of tissue fluids, blood and death of connective tissue cells, all of which form the basis for the development of cal



FIG 277 Note the elongated calcareous amorphous deposit in the substance of the medial longitudinal ligament in the region of the medial femoral condyle Note further that there is a definite interval between the deposit and the surface of the femoral condyle



FIG 278 (*Left*) Note the formation of heterotopic bone in the region of the epicondyle of the femur and also some irregular amorphous deposits of calcium at the level of the joint space The ossified ligament is attached to the epicondyle of the femur At this time the patient was having considerable pain and the process was still in an active state. (*Right*) Depicts the amount of bone and calcerous material excised from the substance of the ligament Although this patient showed considerable improvement, some residual limitation of flexion was apparent

cification and ossification in and about the medial ligament Lesions of this nature are *found in other sites in the body* which are subjected to strains, producing the aforementioned tissue *damage Besides the medial* ligament of the knee joint some of the other sites of predilection of this lesion are the upper attachment of the medial ligament of the elbow joint and the medial ligament of the ankle joint The author has also encountered the disorder in the fibular collateral ligament

Traumatic degeneration and necrosis of tissue together with a localized collection of blood and tissue fluids initiate the pathologic processes which culminate first in the precipitation of calcium salts and ultimately *in ossification The calcareous mass* varies in size from a thin crescent-shaped lesion to one measuring several centimeters in width and length In the formative stage a space usually separates the lesion from the medial aspect of the condyle of the femur this is especially true of thin elongated lesions (Fig 277) In the late stages the mass may fuse with the medial surface of the condyle this feature is encountered more frequently in large lesions which as a rule are the *result of direct violence to the* inner side of the knee joint (Fig 278) In *the early stages of development the lesion* is usually amorphous in nature and poorly defined later, it is replaced by heterotopic bone which is dense, discrete and sharply delineated

Clinical Manifestations

Generally the patient gives a history of some form of direct trauma to the inner aspect of the knee or a rotary *strain which* at first is considered of little importance but after *3 or 4 weeks the persistence and* the gradual accentuation of the symptoms forces the patient to seek medical advice. Occasionally the patient is seen by a physician immediately after the injury and the lesion is treated inadequately as a contusion or a sprain of the knee joint At this stage of the clinical course the pertinent clinical features are (1) more or less constant pain over the region of the femoral attachment of the medial tubercle, (2) *accentuation of the* pain by activity and (3) varying degrees of dysfunction resulting chiefly *from limitation of flexion* of the knee joint

Examination may reveal some slight localized swelling on the inner aspect of the knee palpation discloses that the tissues in the region of the adductor tubercle are slightly thickened pressure over this area invariably elicits severe tenderness In all instances observed by the author limitation of flexion was an outstanding feature and in some cases loss of the last few degrees of *extension was also discernible. When the* knee was forced beyond the arc of free motion the patient experienced sharp excruciating pain The acute symptom signs conforming to this pattern are manifested for 10 to 12 weeks after the initial injury during this period unwise attempts at treatment such as passive manipulation of the knee joint forcing the patient to exercise the limb in spite of pain and rough kneading massage tend to stimulate the proliferative process *rather than promote its recession* In fact the potential danger of enhancing *and prolonging* the evolutionary process is present up to the time when maturity of the lesion is definitely established as evidenced by a decrease in the intensity of the symptoms and the formation of a discrete dense bony mass

Generally after a period of 10 to 12 weeks the intensity *of the process begins to* subside the symptoms are less severe *and although flexion* is still *demonstrable* motion is associated with less pain A firm bony hard tumefaction is now palpable in the region of the adductor tubercle If it ha fused with the medial condyle it is immobile otherwise some motion i demon tra ble Pressure over the ma gives rise to tenderness and flexion *of the joint is re*stricted the extent of the restriction i

governed by the degree of implication of the medial ligament which interferes with the gliding mechanism of the ligament

Roentgenologic Features

As a rule, when the true nature of the lesion is recognized, usually after the third or the fourth week, a thin amorphous elongated semilunar-shaped calcareous deposit is readily demonstrable between the medial surface of the condyle and the lesion (Fig 277) The mass may retain this configuration except, that as it passes into the stage of maturity it becomes more dense and sharply demarcated No appreciable change may occur up to the time that partial or complete absorption occurs On the other hand, proliferation of the lesion may be the outstanding feature. This is particularly true in lesions caused by severe direct violence (Fig 278) At first, the entire growing mass may exhibit a granular ill-defined amorphous character, later, when ossification predominates, it becomes sharp and dense occasionally, bony trabeculae are noted in the roentgenograms Such lesions usually fuse with the medial condyle and are rarely absorbed completely, but usually partial absorption of the mass occurs

Management

The most effective treatment is prevention. This goal can be achieved only by being constantly aware of the potentialities of minor sprains or severe direct trauma to the inner aspect of the knee joint Adequate treatment at this time in the form of complete immobilization of the limb in a plaster cylinder for a period of 4 to 5 weeks, depending upon the severity of the trauma will prevent the process and in very early cases will abort further developments Immediately after the injury overzealous treatments in the form of massage and forced activity must be condemned because such measures may initiate the processes responsible for para-articular calcification and ossification

After the lesion is recognized clinically, usually 3 to 4 weeks following the initial trauma, a nonpadded plaster cylinder is applied from above the malleoli to the mid thigh although weight bearing, quadriceps drill and straight leg raising are permitted on a regulated regimen, strenuous exercises are prohibited. The cylinder is maintained for 4 to 6 weeks, as a rule at the end of this period most of the calcareous mass is absorbed. Subsequent exercises to restore joint motion are performed, always within the painless arcs of motion Forceful passive manipulation or vigorous activity must be avoided throughout the entire formative period Surgical intervention never is justified at any time during this period Failure to adhere to this line of treatment invariably leads to stimulation of the pathologic processes resulting in deposition of calcareous material which eventually culminates in heterotopic bone

Recently, the author has treated 4 early cases with injection of 2 cc. of Hydrocortone into the site of maximum tenderness and resumption of activity without fixation of the limb in plaster In all instances the symptoms subsided within 24 to 48 hours and rapid absorption of the calcareous deposits ensued as demonstrated by roentgenograms Restoration of normal function was achieved in 10 to 14 days The number of cases is too small to permit any conclusions relative to the efficacy of this form of treatment however the results suggest further investigation Some cases, particularly those that are treated unwisely and occasionally even some which have been treated correctly from the onset of the lesion, progress to the stage of maturity in which a large mass of heterotopic bone remains showing little or no evidence of absorption The mass forms a mechanical obstruction to the gliding mechanism of the tibial collateral ligament When the pathologic process is stabilized completely surgical excision of the heterotoxic bone is justified

Technic. A shallow S-shaped incision is made over the inner aspect of the knee beginning slightly above the adductor tubercle and ending 4 to 5 cm below the articular brim of the tibia. The bony mass is excised from the ligament by sharp dissection and if it is fused to the medial condyle of the femur its site of attachment is divided with a sharp thin blade osteotome. At this time gentle manipulation is performed, carrying the tibia through a complete range of motion on the femur. Pump-handle movements are avoided. At the termination of the operation an elastic compression bandage is applied and quadriceps exercises are started at once. After the acute reaction of the tissues has subsided—usually 3 to 5 days postoperatively—exercises to restore normal flexion are added; they should not be performed vigorously and always should be executed within the patient's tolerance of pain.

Case Report of Injudicious Management of a Contusion to the Inner Aspect of the Knee.

C. R., a Negro male 46 years of age, was struck by a piece of falling timber on the medial aspect of the left knee joint. Although he had some pain on the inner aspect of the knee, he was able to continue with his work. Several hours later he noticed some localized swelling on the inner aspect of the joint but considered the lesion to be a simple contusion so he applied home remedies and an elastic bandage. He continued to work for 4 weeks, during which time pain was constant and intense; he walked with the knee slightly flexed. A consulting physician made the diagnosis of sprain of the knee joint and prescribed diathermy and knee-bending exercises. At the end of 2 months the knee was manipulated for "adhesions" under a general anesthesia. Because no improvement ensued the knee was manipulated again approximately 6 weeks after the first manipulation. After the first manipulation the patient was unable to return to work; after the second manipulation treatment consisted of radiant heat, massage and exercises.

The patient was seen in the Jefferson Hospital approximately 8 months after the initial injury. Examination at this time revealed pronounced atrophy of the quadriceps muscle, the knee was held in 30° of flexion, and the patient walked on his toes. A firm mass was palpable over the adductor tubercle which was painful on pressure; free flexion was possible only within the arc from 150° to 100°. Attempts to increase the arc of flexion elicited severe pain; spasm of the hamstring muscles precluded any increase in extension. Roentgenographic study revealed the presence of a large, dense semilunar shaped mass overlying the medial condyle; the heterotopic bone had fused with the upper end of the condyle. At the level of the joint several amorphous granular deposits were observed. It became apparent that the upper limits of the lesion were more or less stabilized and had reached maturity while the lower portion was still in a proliferative state (Fig. 278 *left*).

The patient was given a general anesthesia (Pentothal Sodium); with relaxation of the flexor muscles of the affected limb the extremity spontaneously assumed the position of complete extension. A plaster cylinder was applied and mild quadriceps drill was commenced at once; only protective weight-bearing was permitted. The cast was removed at the end of 6 weeks, at which time the pain had completely subsided; the tumefaction on the inner side of the knee was smaller but firm and not particularly tender. Flexion was still restricted but some of this was due to the period of fixation. Quadriceps exercises were increased in intensity but no manipulative measures were employed and flexion exercises were not encouraged. After 2 more months (almost 13 to 14 months) after the accident the heterotopic bone was excised from the quadriceps ligament and divided from its attachment to the medial condyle (Fig. 278 *right*). In addition the knee was gently put through a full range of motion. Now quadriceps and flexion exercises were increased slowly in intensity. Within 3 months the patient had no pain, the knee was stable, and he had returned to his former employment. However 6 months after the operation he still had 15 to 20° restriction of flexion; extension was complete.

OLD LESIONS OF THE LIGAMENTS OF THE KNEE JOINT

General Considerations

Old lesions of the ligaments sufficient to produce pronounced dysfunction are rarely observed as isolated lesions. Old ruptures

of the anterior cruciate ligament without implication of other structures are encountered more frequently than isolated lesions of the remaining components of the ligamentous apparatus When rupture of the anterior cruciate ligament is present in a joint whose function is impaired markedly, invariably examination will disclose a lesion of the medial meniscus or relaxation or rupture of the tibial collateral ligament or both. Also there may be advanced relaxation of the capsule and the extensor apparatus and loss of quadriceps tone and volume Old ruptures of the tibial collateral ligament are rare as isolated lesions, generally, a torn or attenuated anterior cruciate ligament and a tear of one or both of the menisci are concomitant findings This triad is responsible for the most severe form of dysfunction encountered, the severity of quadriceps atrophy and capsular relaxation, which are invariably associated with this disabling combination add, in a large measure, to the extent of the impairment of joint function

Surgical intervention is rarely justified in cases of isolated injuries because in most instances the extensor apparatus can be developed to a high level of efficiency sufficient to compensate for the defective structure Although these joints are not capable of meeting the demands of rigorous athletic activity they can meet the requirements of everyday normal activity Moreover because the musculature of the thigh plays such an important role in the over all performance of the knee and is the chief stabilizing factor of the joint, no operative procedure should be undertaken without first giving due consideration to the redevelopment of the extensor mechanism. At best, accepted reconstructive procedures, together with a quadriceps developed to the level of maximum efficiency produce a knee joint which is far from normal but decreases the extent of the disability and provides the patient with a limb capable of performing the average daily tasks On the other hand the most meticulously executed procedure is doomed to failure if the extensor apparatus has been neglected Development of muscle power must not be concentrated on the quadriceps alone but also on the muscles of the hip and the calf, all of which have a specific and pertinent role in the stabilization of the knee joint

Management of old ruptures presents more intricate and serious problems than treatment of recent ruptures In the latter restoration of the normal anatomy can be achieved in most instances, whereas in old lesions the "golden period" of repair has long passed, and the only alternative remaining is the reconstruction of substitutes for the disrupted structures Man is not able to reconstruct ligaments which possess the inherent intrinsic mechanism of the normal structures For example, the arrangement of the fibers of the cruciate ligaments which permits shifting of the tension from one group of fibers to another group during flexion and extension cannot be reproduced by the most dexterous surgeon This is also true of the tibial collateral ligament In addition, the replica lack the important sensory innervation which makes the entire ligamentous apparatus and capsule a living part of the knee joint this feature protects the joint from abnormal stresses by calling into play the protective mechanism of the muscles crossing the joint. In long neglected cases repeated incidents of giving way which are associated with an unstable joint may result eventually in irreparable damage to all the joint structures traumatic arthritis is a frequent sequela in these cases The damage may be so profound that the only recourse which will provide a painless and useful limb is arthrodesis of the joint

In the light of this information, when a surgeon assumes the responsibility of reconstructing old ruptured ligaments he should do so with the mental reservation that at best he can only lessen the existing disability and that this can be achieved only after the quadriceps has been redeveloped to maximum efficiency Also, the patient

should be made aware of this fact in order that his expectations may not be too great otherwise, disappointment is inevitable

Pathogenesis and Clinical Features of Old Ruptures

Rupture of the Tibial Collateral Ligament. In the section dealing with acute injuries of this ligament it was pointed out that acute complete ruptures are often associated with rupture of the anterior cruciate ligament and in some instances also a tear of one or both menisci a combination which invariably produces profound disability if early repair is not effected However, isolated lesions are relatively common and, if treated inadequately will give rise to varying degrees of disability Failure to achieve normal anatomic restoration of the structure by surgical measures immediately after the accident and disregard for the importance of the extensor mechanism in the presence of this lesion are the chief factors for the impairment of function which ensues Depending upon the extent of impairment of the extensor mechanism varying degrees of lateral instability of the joint are discernible This instability is responsible for recurrent episodes of buckling and giving way of the joint on weight bearing with the knee in varying degrees of flexion and also makes the medial meniscus vulnerable to recurrent trappings between the condyles of the femur and the tibia For this reason in old cases in addition to severe quadriceps atrophy capsular relaxation and lateral instability a longitudinal tear of the medial meniscus may be an associated finding The presence or the absence of this meniscal lesion always must be determined before one can treat intelligently a supposedly isolated lesion of the medial ligament

Clinical Manifestations Cases of sufficient severity to cause patients to seek medical aid invariably give a history of some form of severe abduction or rotary injury to the knee joint Subsequentl individuals note a sense of instability and a tendency for the knee to buckle inward particularly when the patient is caught off guard with the knee flexed Frequently the incidences are accompanied by swelling of the knee joint and pain along the inner aspect of the joint. There is a tendency for the severity of each incident to progress in intensity this is also true of the degree of dysfunction after each episode Although the patients in most instances are capable of performing ordinary daily activities, they find themselves unable to participate in athletic pursuits.

In the event that a tear of the anterior cruciate ligament exists, the aforementioned symptoms and the extent of the impairment of function are greatly exaggerated If one of the menisci is implicated momentary locking or even complete locking of the joint may occur In very old cases the amount of effusion following each locking may be insignificant In one instance the author reduced a displaced medial meniscus in the same patient on three different occasions within a period of 3 weeks After each episode the joint tissues showed little or no reaction

Examination in uncomplicated ruptures of the medial ligament causing marked dysfunction always reveals advanced quadriceps atrophy and varying degrees of laxity of the extensor mechanism, the ligamentous apparatus and the capsule With the knee in slight flexion abnormal abduction rocking is demonstrable often this maneuver is accompanied by an audible click as the joint surfaces snap back into position. Abnormal rotation of the flexed tibia on the femur is readily discernible and is the result of general laxity of the tissues some abnormal anterior di placement of the tibia on the femur is demonstrable Defects in the long vertical portion of the ligament may be palpated while the knee is held in extension and abduction

All clinical signs ... kedly exagger ted in combined ... cause of dis

solution of the anterior cruciate ligaments and laxity of the supporting structures, forward displacement of the tibia is now maximal the test for abduction rocking produces wide separation of the articular surfaces of the tibia and the femur on the medial side of the joint in the flexed, the extended and the hyperextended positions In the flexed position, rotation of the femur is increased in both the medial and the lateral directions, lateral rotation is increased because of the dissolution of the medial ligament and laxity of the other supporting structures, and abnormal medial rotation is permitted chiefly by the rupture of the anterior cruciate ligament

Roentgenograms taken with the knees flexed (15 to 20) and bound and the legs wedged apart with sandbags exhibit widening of the medial joint space, in the event that rupture of the anterior cruciate ligament takes the form of a sprain fracture of the tibial spine, the displaced fragment is visualized

Old Rupture of the Anterior Cruciate Ligament. Old isolated ruptures of this structure are encountered more frequently than old isolated lesions of the medial ligament Fortunately, the extent of joint impairment associated with this disorder is less than that produced by lesions of the medial ligament. If the extensor apparatus compensates for the defective structure the degree of dysfunction is minimal nevertheless most of the individuals affected possess enough disability to preclude participation in strenuous pursuits Those patients who seek medical advice usually exhibit varying degrees of quadriceps inefficiency and laxity of the other supporting components of the knee joint, which is the true factor responsible for impaired joint function. In the latter instances recurrent episodes of giving way of the joint followed by effusion and periods of inactivity predispose the medial meniscus and the medial ligament to repeated injuries As pointed out previously, rupture of the anterior cruciate ligament and tearing of the medial and the lateral menisci may occur at the time of the original accident, being produced by the same mechanism. On the other hand, the initial lesion may have been a tear of the meniscus, usually the medial repeated incidences of locking may result in stretching and even rupture of the anterior cruciate ligament The mechanism whereby this occurs is recorded by Helfet This observer points out that the prime function of the cruciate ligaments is to act as guide ropes for the path of the tibia during rotation at the knee joint. This rotation occurs in the last 30° to 40° of extension and in the final degrees of flexion. The configuration of the articular surfaces of the medial condyle determines the course of the tibia during flexion and extension, but the ligaments guide the tibia in its paths During the last phase of extension (screw home movement), some portion of the anterior cruciate remains tense at all times, guiding the lateral rotation of the tibia on the femur However, if lateral rotation of the tibia is resisted while extension of the joint continues, the tension in the anterior cruciate ligament increases and at the same time hooks over the lateral margin of the medial condyle of the femur It becomes apparent that any obstruction to normal lateral rotation of the tibia during the terminal phase of extension may stretch or tear the anterior cruciate ligament

The posterior cruciate ligament guides the tibia on its path in relation to the femur in the last degrees of flexion During this phase of flexion some portion of the posterior cruciate is tense if medial rotation of the tibia is obstructed and flexion continues the posterior ligament may be stretched or torn It becomes obvious that the synchronous rotation of the tibia on the femur is essential for normal extension and flexion of the joint any form of obstruction to this rotary motion may result in a rupture of one of the cruciate ligament•

The above mechanism affords an explanation for the high incidence of rupture or stretching of the anterior cruciate ligament encountered as a concomitant finding with tears of the medial meniscus Repeated momentary lockings and weight bearing on the flexed knee joint, when true locking exists as a result of a displaced meniscus, prevent normal lateral rotation of the tibia on the femur in the terminal phase of extension When these conditions prevail attempts at extension of the joint stretch the anterior cruciate ligament

The anteroposterior instability resulting from rupture of the anterior cruciate ligament and atrophy of the extensor apparatus may cause stretching and weakness of the medial ligament This may occur in the presence or the absence of a tear of the medial meniscus In the latter instance, the medial meniscus is extremely vulnerable to injury because of the pronounced instability which is usually present.

Clinical Manifestations In cases with uncomplicated tears of the anterior cruciate ligament and in which the extensor mechanism is capable of performing at maximum efficiency, the extent of joint disability is for practical purposes insignificant. These patients have a history of an original injury with few or no incidents of giving way of the knee joint. They know that the affected knee cannot meet the demands of strenuous activity required in basketball or football

If repeated episodes of anteroposterior instability occur and are accompanied by effusions and muscular inactivity the quadriceps muscle shows varying degrees of loss of volume tone and power laxity of the remaining supporting structures of the joint may ensue Even without stretching or rupture of the medial ligament Isolated lesions of the anterior cruciate ligament allow some abnormal forward gliding of the tibia on the femur (positive anterior drawer sign) The amount of displacement may be increased if marked laxity of the supporting structures exists If it is maximal then suspicion must be directed to a lesion of the medial ligament In cases with marked laxity of all the soft tissue elements of the joint but without rupture of the medial ligament, forward displacement of the tibia is always present and it may be difficult to determine the presence or the absence of a lesion of the anterior cruciate ligament the amount of displacement noted always should be compared with that observed on the unaffected side

In combined lesions the signs and the symptoms indicating implication of one or both menisci or the medial collateral ligament are present These have been discussed fully in the section dealing with ruptures of the tibial collateral ligament

Old Ruptures of the Posterior Cruciate Ligament. Old isolated lesions of this structure are extremely rare however, when they do occur they are capable of producing marked instability of the knee joint, provided that there is laxity of the supporting elements of the joint the extensor apparatus discloses loss of volume and power The author has encountered 4 cases who sought medical advice because of the existing disability In one the lesion comprised an avulsion of a portion of the superoposterior surface of the tibia

These cases exhibit varying degrees of quadriceps inefficiency resulting from muscle atrophy loss of tone and power With the knee flexed the posterior drawer sign can be elicited Some of the patients can produce voluntarily the characteristic features of a posterior drawer sign With the knee flexed and the foot held firmly on the floor forceful contraction of the hamstring muscles pulls the tibia backward in relation to the femur If there is extreme laxity of the posterior supporting structures of the joint abnormal hyperextension of the knee joint is demonstrable These patients are aware of a sense of instability on weight bearing when the knee is in varying positions of flexion The instability may

be in the lateral, the anteroposterior or both directions and is primarily the result of failure of the tibia to rotate medially when the knee is bearing weight in flexion As recorded previously, the tibia is guided on its path of medial rotation on the femur by the posterior cruciate ligament this function is lost when dissolution of the ligament occurs

Old Lesions of the Fibular Collateral Ligament. Old isolated lesions of this structure requiring treatment must be extremely rare, the author never has encountered one However he has observed one old lesion of the fibular collateral ligament associated with a tear of both cruciate ligaments In this case there was marked instability of the joint the tibia exhibited abnormal anteroposterior gliding on the femur (anterior and posterior drawer signs) and abnormal adduction rocking with the knee in both extension and flexion The external popliteal nerve was not involved

Management of Old Ruptures of the Ligaments

As so often pointed out in this work, the quadriceps apparatus is the most important stabilizer of the knee joint Also ruptures of one ligament, such as the anterior cruciate or the medial without the presence of internal derangement, particularly a tear of one of the menisci are compatible with good function provided that the quadriceps is developed to that level of performance sufficient to compensate for the defective structure In the light of this information it becomes apparent that uncomplicated lesions of any one of the ligaments of sufficient severity to produce marked disability should be treated by conservative measures designed to redevelop the extensor apparatus to its maximum level of efficiency this is particularly applicable to lesions of the anterior cruciate and the tibial collateral ligaments

Medial Ligament. In the event that this form of therapy fails to achieve the desired result in cases of old ruptures of the medial ligament, surgical intervention is justifiable However, both the surgeon and the patient should be fully cognizant of the extent of the benefits to be derived from reconstructive procedures As recorded previously, at best the replica will enhance the stability passively but the over all performance of the joint will not be comparable with that of the normal side As will be noted subsequently, the operations of Helfet are the only procedures that attempt to replace ruptured ligaments with "living" substitutes In other procedures the reconstructed ligaments are merely complements to the stabilization effected by a redeveloped extensor mechanism this is true not only of reconstruction of the medial ligament but also of all the other components of the ligamentous apparatus

In uncomplicated ruptures of the medial ligament, conservative measures which comprise essentially progressive quadriceps exercises must be continued as long as improvement continues, it may require from 2 to 5 months to achieve the desired results If at the end of this period, the quadriceps fails to provide adequate stability to the joint reconstruction of the ligament must be considered No case should be subjected to surgery until every effort has been expended to develop the quadriceps to its level of maximum efficiency

Occasionally cases are encountered in which attainment of this goal is deterred by the presence of some form of internal derangement, such as a tear of one or both menisci It is obvious that the meniscal lesion must be eliminated before embarking on a long regimen of conservative treatment. In such cases the author removes the involved meniscus and reinforces the medial ligament by transplantation of the tendon of the semitendinosus muscle according to the technic of Helfet This procedure is also performed in combination with medial displacement of the tibial tu

bercle when both the medial and the anterior cruciate ligaments are impaired. Likewise, combined lesions of the medial and the anterior cruciate ligament without *implication of one of the menisci must* not be submitted to reconstructive measures until it becomes apparent that progressive quadriceps exercises have failed to produce sufficient stability of the joint compatible with good *function and to safeguard the* joint from further disintegration.

Anterior Cruciate Ligament. The author never has encountered an isolated old rupture of the anterior cruciate ligament which has required surgical intervention. In such cases that come to the attention of *the surgeon the dysfunction is the result* of laxity of the capsule and the extensor mechanism; they respond readily to intensive resistant exercises that restore volume control and tone to the quadriceps *muscle. However the problem is not so* simple when a meniscal lesion complicates the picture and such cases are relatively frequent. If the meniscal lesion is responsible for recurrent incidences of giving way which hinder the enforcement of the conservative regimen and are prone to *enhance deterioration of the supporting structures* of the joint, then removal of the offending cartilage is imperative before quadriceps exercises are instituted.

It was recorded previously that rupture *of the anterior cruciate* ligament renders the medial collateral ligament vulnerable to repeated traumata resulting in stretching of the structure. Again, if quadriceps redevelopment fails to produce the desired stability and protection necessary to preclude further damage to the joint, recon*struction of the impaired elements* is imperative.

Posterior Cruciate Ligament. Conservative measures are also indicated in isolated lesions *of the* posterior cruciate *ligament* producing undesirable clinical manifestations. In the author's experience of the 4 cases which failed to be benefited by these measures one *revealed avulsion of* a fragment of bone from the superoposte*rior aspect of the tibia*; this was replaced; the remaining 3 were benefited sufficiently to decrease their disability by transplantation of the intact tendon of the semitendinosus muscle to the medial femoral condyle *in the line of the medial ligament.* As pointed out by Helfet this procedure *permits active* internal rotation of the tibia in flexion which is the chief function of the *posterior cruciate ligament*. The operative procedures must be followed by an intensive program of progressive quadriceps and hamstring exercises.

RECONSTRUCTION OF THE LIGAMENTS OF THE KNEE JOINT

The indications for reconstruction of the different ligaments singly or in combination have been discussed in the previous *section. Here it is necessary only to record* the types of operative procedures which are most likely to produce the highest incidence of satisfactory results. In 1917 Hey Groves recorded a method of reconstruction of the anterior cruciate ligament by using a strip of fascia lata; this procedure was modified *later by Smith (1918) who added a method of repair of the medial ligament.* Since these two operations were recorded numerous other technics have been conceived using either fascia lata or tendons to substitute for the ruptured structures. A survey of the literature discloses that the success or the *failure of many of these methods* varied in the hands of different surgeons. However certain observations become very apparent. (1) All inarticular procedures are technically difficult. (2) Most of these methods entail extensive exposure of the joint and of its supporting tissues. (3) Although the *successful execution of the* procedures depended on the dexterity of the surgeon *many of the methods failed to produce* the desired results even in the hands of the most skillful. (4) Cases unwisely selected were doomed to failure. (5) The methods

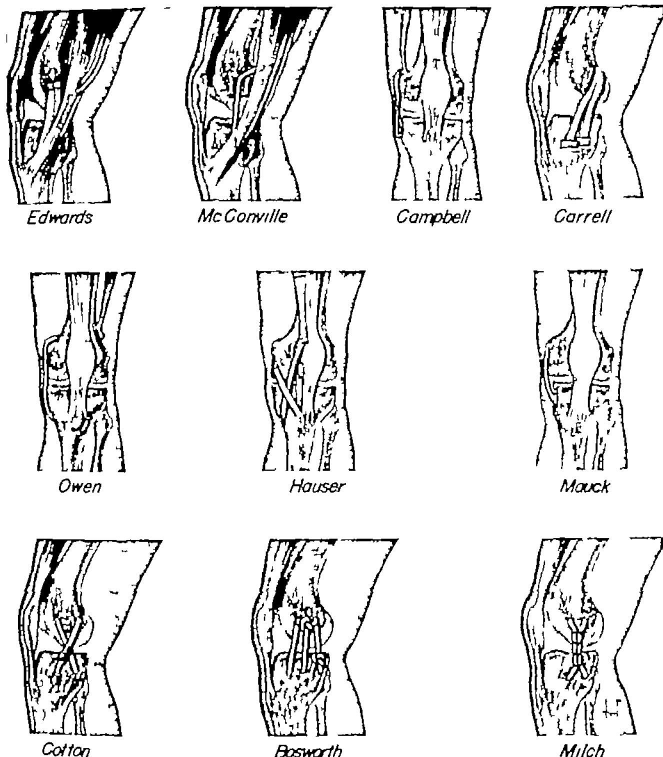


FIG. 279 Some of the methods of reconstruction of the ligaments of the knee joint described by different writers.

which utilized living structures to reconstruct the ligaments invariably produced more satisfactory results than those which utilized fascia lata and completely detached segments of tendons (6) Regardless of the methods employed, redevelopment of the quadriceps muscles played a major role in the success of the operation

The author has employed many of the methods recorded and finally has come to the conclusion that in properly selected cases, the procedures which are followed by

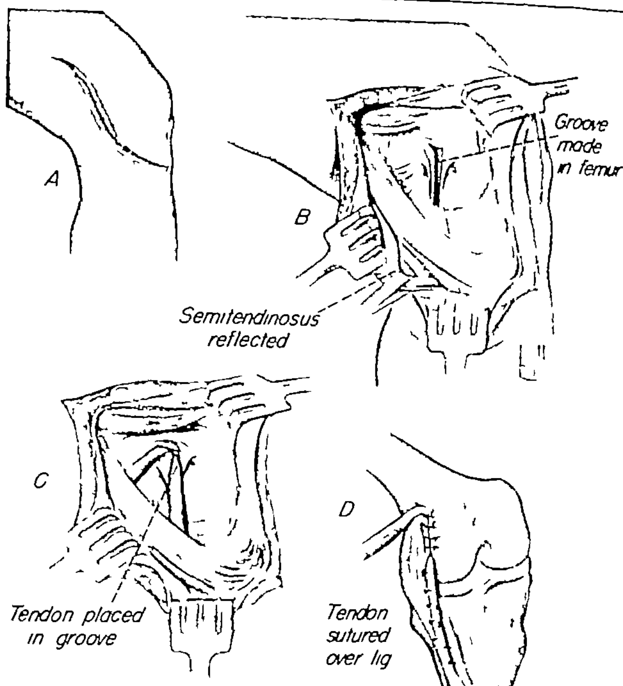


FIG 280 (A B and C) Transplantation of the tendon of semitendinosus muscle to the lateral aspect of the medial femoral condyle (D) Note that the tendon is in line with the tibial collateral ligament. This operation is performed to replace the function of a torn posterior cruciate ligament and to reinforce a torn or weakened medial collateral ligament.

the highest incidence of satisfactory results both to patient and surgeon are those which are performed with minimal surgery and utilize living structures to replace the ruptured ligaments Other workers have reached this conclusion notably among these are Helfet Hauser Blair and Smillie For the sake of completion and for academic and historical interest some of the many methods conceived are depicted in Figure 279 The operative procedures described herein are the ones which the author now employs

Reconstruction of Tibial Collateral Ligament. In the author s hands the operation of Helfet which is a modification of

the McMurray procedure, has proved to be the most effective method of reconstruction of the medial ligament. Essentially, it is a transposition of the tendon of the semi tendinosus muscle In the operation described by McMurray the tendon was anchored in two grooves one was made on the medial aspect of the tibia and the other on the femur Helfet placed the tendon in one tunnel situated in the femoral condyle the tendon is free in the tunnel and acts as a live ligament. It is a substitute for the posterior cruciate ligament and also reinforces the medial collateral ligament The position of the new ligament permits the semitendinosus to function as an active internal rotator of the tibia when the knee is in different positions of flexion, this is primarily the function of the posterior cruciate ligament

Operative Technic (Fig 280) A shallow S-shaped incision is made on the medial aspect of the knee beginning 2 cm above the medial femoral epicondyle and terminating on the medial aspect of the tibia 6 cm below the articular brim of the tibia. The fascia is divided by a vertical incision, exposing the medial ligament throughout its entire length. The inner skin flap is dissected from the fascia, and the tendon of the semitendinosus is identified it lies posterior to the tendons of the sartorius the gracilis and the semimembranosus muscles By sharp dissection the tendon is freed from the surrounding structures distally as far as its site of insertion. Care must be taken not to injure the saphenous nerve in the proximal end of the wound The fascia and the periosteum on the medial aspect of the femoral condyle are divided vertically in the line of the medial ligament and then are reflected on each side exposing the raw bone A groove extending from the upper border of the femoral condyle to the reflection of the synovium of the knee joint 1 cm wide and 1½ cm deep is cut out of the inner condyle with a thin sharp osteotome The groove is directed slightly inward and backward, this direction minimizes the tendency of the tendon to dislocate, the maximum depth of the groove is at its center Next, the long fibers of the anterior portion of the medial ligament are divided longitudinally With the knee flexed 30°, the tendon is brought forward between the bone and the tendons of the semimembranosus, the gracilis and the sartorius muscles and levered into the groove The edges of the fascia and the periosteum are carefully approximated over the groove by interrupted cotton sutures, creating a tunnel in which the tendon can glide freely The tendon distal to the lower aperture of the tunnel is placed between the split fibers of the medial ligament and fastened to the fibers on each side by interrupted sutures At this point, particular care should be taken not to anchor the new and the old ligaments to the surrounding tissues the gliding mechanism of the medial ligament should be preserved. If it is obliterated restriction of flexion will ensue

In the event that a tear of the meniscus is a concomitant lesion, the joint can be exposed by an oblique incision anterior to the long anterior fibers of the tibial collateral ligament. This incision provides ample exposure for excision of the affected meniscus

The wound is closed in layers in the usual manner, using interrupted cotton sutures At the termination of the operation on elastic compression bandage is applied from mid-calf to mid thigh, and the limb is placed in a posterior molded plaster splint holding the limb in the extended position Quadriceps exercises and straight leg raising are commenced at once, but no flexion of the knee is permitted for two weeks At the end of this period, flexion exercises are added and quadriceps exercises are intensified. Weight bearing is permitted after 5 to 7 weeks, depending upon the degree of quadriceps power and control that has been achieved during this period



Fig 281 Smillie's method of transplantation of the tibial tubercle to the anteromedial aspect of the tibia. *This procedure is employed when there is a tear of the* anterior cruciate ligament also it is used to enforce the ligamentous apparatus on the medial side of the joint. (A) Skin incision employed. (B) Line of incision for detachment of the tibial tubercle and elevation of the patellar tendon (C) A rectangular slot is cut out of the anteromedial aspect of the tibia (D) Method of implanting the tubercle in the slot.

Substitution for the Anterior Cruciate Ligament. As pointed out previously isolated *lesions of the anterior cruciate ligament* do not require surgical intervention satisfactory stability of the joint can be attained by *redevelopment of the extensor* apparatus When the lesion is encountered in combination with a stretched or torn medial ligament satisfactory stability and function can be achieved by transplantation of the tibial tubercle to the anteromedial aspect of the tibia Helfet points out that this procedure permits the quadriceps muscle to rotate the tibia outwardly when the knee is extended and hence re-establishes normal function of the defective anterior cruciate ligament In combined lesions this procedure is performed in addition to transposition of the tendon of the semitendinosus to the medial aspect of the femur which reinforces the medial ligament The new direction of the transplanted *patellar tendon is downward and inward* crossing the joint line Contraction of the quadriceps during joint motion makes the *tendon tense hence it now acts as an* active medial ligament in addition to an active external rotator of the tibia If a *lesion of the medial meniscus is present the* fibrocartilage may be excised in the manner described in the section dealing with reconstruction of the medial ligament All three procedures may be done at the one operation

Operative Technic (*Smillie*) (Fig 281) On the medial aspect of the knee joint an S-shaped incision is made beginning 2 cm proximal to the femoral epicondyle and just distal to the tibial tub[illegible] lower limb of the incision

extends outward to the crest of the tibia. The entire tibial tubercle, with the patellar tendon attached, is removed with a thin blade sharp osteotome. This segment of cortical bone is rectangular in shape and measures 1½ by ½ inches A defect corresponding in size to that of the cortical bone removed is outlined and made on the inner and anterior aspect of the tibia at a slightly lower level than its original location the long axis of the slot is placed at an angle of 45° with the vertical axis of the tibia. With a curet the slot is deepened also, cancellous bone is removed from beneath cortical bone proximally and distally so that the bony plate to which the patellar tendon is attached can be rotated in its new bed and locked beneath the edges of the slot. The detached tibial tubercle is next placed deeply in the defect and rotated into position so that now it lies below the level of the cortical bone, and its longitudinal axis coincides with that of the quadriceps muscle

The postoperative management is similar to that described following the transplantation of the tendon of the semitendinosus muscle.

Although these procedures increase lateral stability of the joint, anteroposterior displacement of the tibia can still be demonstrated passively However during active motion the transplants restore normal rotation of the tibia hence the patient has active control of the leg and with redevelopment of the quadriceps and the hamstring muscles stability is improved The author has performed the aforementioned procedures in the last 8 cases of old combined lesions In all the end results were satisfactory to the point that the patients were all able to return to gainful employment and had limbs which were capable of meeting the ordinary demands of daily life (Fig 282)



FIG 282 Note the position of the transplanted tibial tubercle to the anteromedial aspect of the tibia In this instance the tibial tubercle was transplanted to restore external rotation of the tibia in extension and to reinforce a stretched and weakened tibial collateral ligament.

Smillie has recorded an ingenious method of restoration of the anterior cruciate ligament in which he utilizes the peripheral half of the medial meniscus The fibrocartilage is dissected free except at its anterior attachment the concave portion of the meniscus is excised and the peripheral segment is passed through a drill hole in the lateral femoral condyle He recommends this procedure in cases in which a torn anterior cruciate ligament is an associated feature of a tear of the medial meniscus requiring surgical intervention or it may be combined with other procedures in which a lesion of the medial ligament is present and needs reconstruction He suggests that it may be used in combination with transplantation of the patellar tendon or the operation of Blair which is an extra

articular method of reconstructing the collateral ligaments.

Old Rupture of the Posterior Cruciate Ligament. As noted previously 4 such cases have been encountered In one a fragment of bone was avulsed from the superoposterior aspect of the tibia This was exposed by a posterior incision and anchored to its normal site by suturing it to the surrounding capsular tissue as in recent lesions The remaining 3 cases were treated by transplantation of the semitendinosus muscle as described previously Intensive quadriceps and hamstring exercises are essential to produce satisfactory results.

Old Rupture of the Fibular Collateral

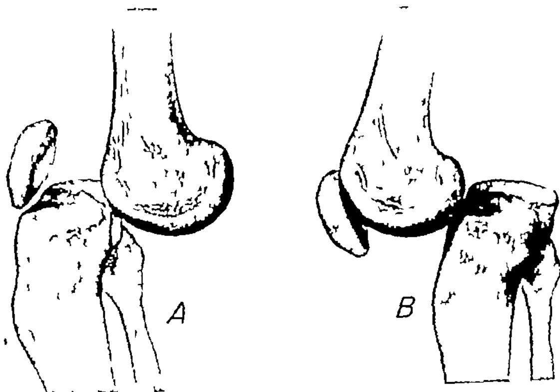


FIG 283 The different types of dislocations. (A) Anterior dislocation. (B) Posterior dislocation (C) Lateral dislocation. (D) Medial dislocation



Ligament. If such an occasion should arise, the ligament can be reconstructed readily by utilizing a segment of the tendon of the biceps femoris muscle The distal end is left attached to the head of the fibula while the proximal end is anchored in a long groove in the lateral condyle The technic is similar to that described for recent tears of the fibular ligament (Fig 270)

TRAUMATIC DISLOCATION OF THE KNEE JOINT

The combined strength of the supportive elements of the knee joint is sufficient to render dislocations a very rare lesion When they occur great direct violence must be applied which invariably results in profound disruption of the supportive tissues of the joint and at times fracture of the upper end of the tibia Occasionally the injury is produced by severe rotary forces or a force applied through leverage

Varieties of Dislocation (Fig 283) Generally the direction of the acting force determines the type of dislocation. The dislocation may be partial or complete, the tibia may be displaced in relation to the femur anteriorly posteriorly, internally or externally, or it may be rotated inwardly or outwardly on the femur Any of the types enumerated may be complicated by a fracture of the tibia, usually implicating its upper end The most frequent variety encountered is the anterior dislocation which results from forceful hyperextension of the knee joint A violent force applied to the anterior surface of the upper end of the tibia when the femur is fixed produces a posterior dislocation Medial and lateral dislocations may be produced by direct violence or by severe abduction or adduction strains

Pathology In order to permit complete dislocation of the massive ends of the femur and the tibia, of necessity the soft tissue structures must undergo severe stretching and tearing As a rule, complete lesions result in rupture of both cruciates both collateral ligaments and the posterior portion of the capsule In addition, the hamstring muscles, the popliteus both heads of

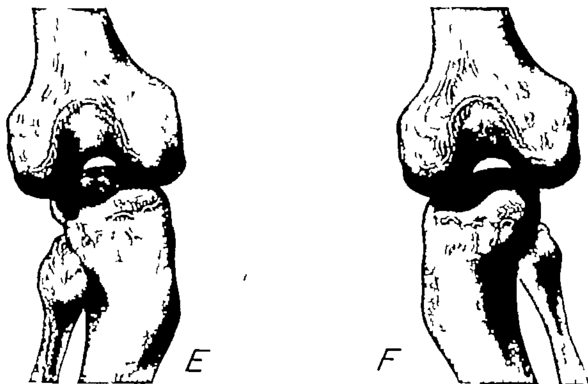


FIG 283 (E and F) Rotatory dislocations.

the gastrocnemius muscle and the quadriceps may suffer varying degrees of laceration. Lateral dislocations may inflict irreparable damage to the external popliteal nerve. The neurovascular structures in the popliteal fossa may be traumatized, resulting in gangrene of the lower leg and necessitating amputation. Inasmuch as the joint is relatively superficial, the overlying soft tissues may be severed completely, thereby establishing direct communication between the joint cavity and the exterior. As noted previously, fracture of the upper end of the tibia may be a concomitant finding.

Clinical Features. The superficial position of the joint makes the diagnosis of complete dislocations a simple matter. Inspection reveals immediately the gross deformity present and the relation of the upper end of the tibia to the femur. Pronounced soft tissue swelling may obscure the true nature of the deformity in partial dislocations; however, gentle palpation of the bone landmarks of the knee joint reveals the abnormal position of the condyles of the tibia in relation to the condyles of the femur and the patella. Gentle manipulation discloses the extent of abnormal motion at the joint resulting from rupture of the cruciate and the collateral ligaments. Damage to the external popliteal nerve is manifest by paralysis of the anterior tibial muscles and loss of sensation on the anterolateral aspect of the leg and the foot. The circulatory status of the leg should be determined at this time; a cold blanched lower leg with absence of pulsation in the dorsal pedal and posterior tibial arteries points to injury of the popliteal artery. Roentgenologic studies disclose the true nature of the dislocation and establish the absence or the presence of fractures of the



FIG 284 A case of complete anterior dislocation in a male 21 years old. This patient was treated by conservative measures. Although there was considerable residual restriction of flexion the patient did attain a relatively stable knee and his condition did not necessitate surgical intervention.

condyles or the spines of the tibia (Fig 284)

Management. A general anesthetic agent should be administered before any attempts at reduction are made Generally, the extensive soft tissue disruption associated with the lesions facilitates the reduction of the dislocations Reduction should be achieved as soon after the accident as conditions warrant. In most instances it is accomplished by simple straight traction on the leg and countertraction on the thigh, while the traction is maintained the tibia is forced manually into its normal anatomic position In anterior dislocations the above method may fail and it may be necessary to hyperextend the knee, making direct pressure on the anterior surface of the upper end of the knee so that the tibial condyles engage the femoral condyles then reduction is achieved by flexing the knee joint This method should be executed with great care and only after other methods have failed, because the procedure may traumatize the nerves and the vessels on the posterior aspect of the knee joint

In some medial and lateral dislocations the capsule may be drawn into the joint, precluding complete reduction by closed methods these cases require surgical measures to remove the barriers to reduction. Another type of dislocation which resists reduction by the aforementioned manipulative maneuvers is a lateral dislocation in which the medial hamstring muscles and the sartorius and the gracilis muscles are displaced into the intercondylar notch of the femur In this type it is necessary first to flex the knee to a right angle before the tibia is forced manually into its normal position in relation to the femur

After reduction has been achieved, the joint is aspirated, usually, large quantities of blood and synovial fluid are removed. An elastic compression bandage is applied extending from mid thigh to mid-calf, and the extremity is immobilized on a molded posterior plaster splint, extending from the toes to the groin, holding the foot dorsiflexed 90° and the knee flexed 20 The limb is elevated and the circulation of the toes is watched carefully A second aspiration of the joint may be necessary after 2 or 3 days Usually, at the end of 7 to 10 days the swelling has subsided sufficiently to allow the application of a nonpadded plaster cylinder from the groin to immediately above the malleoli, now progressive quadriceps exercises are instituted A more snug fitting plaster cylinder is applied at the end of 3 weeks, and weight bearing on crutches is permitted. Immobilization is continued for 10 to 14 weeks during this period a concerted effort is made to redevelop the quadriceps to its level of maximum efficiency After the last plaster cylinder is removed (12 to 14 weeks after the injury), crutches should be used until the extensor apparatus has regained sufficient power and control to provide the desired stability and protection to the knee joint.

Even in the most competent hands these knee joints exhibit some residual dysfunction Varying degrees of restriction of flexion is the usual sequela, however, this may be desirable because greater ranges of motion may be accompanied by more instability

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Fig 286 Unusual type of supracondylar fracture The distal fragment is displaced anteriorly the proximal fragment, posteriorly

becomes apparent that the chosen method of treatment must not in itself be an obstacle to restoration of maximum function

It is true that each case is peculiar unto itself nevertheless clinical experience permits making some generalizations Early and repeated aspirations of blood from the joint cavity tend to minimize unfavorable reactions on the part of the synovialis and tend to prevent the formation of intra articular adhesions Closed methods are preferred to open methods except where closed methods fail to produce the desired reduction. Prolonged immobilization favors the formation of intra articular adhesions and loss of muscle power and volume hence early mobilization of the limb is desirable

Supracondylar Fractures

Position of Fragments

As recorded previously supracondylar fractures usually are caused by violent di



Fig 287 Supracondylar fracture with anterior displacement of distal fragment There is some comminution at the fracture site

rect trauma and occasionally by torsion forces. Generally, the line of fracture is transverse and slightly irregular or it may be slightly oblique from before backward Occasionally, varying degrees of comminution of the distal fragment occur while the proximal end is pointed like a projecting spike In some instances the proximal fragment may be impacted into the supracondylar fragment, this is not unusual in children. As a rule, the fracture line occupies an intra-articular position, and the joint capsule is severely lacerated so that a massive hemarthrosis ensues

In most instances the fragments are displaced completely and assume a characteristic deformity in response to the pull of muscles which cross the joint line (Fig 285) The distal fragment is tilted into the popliteal space by the gastrocnemius muscle while the hamstrings and the quadriceps muscle tend to shorten the length of the femur this action forces the distal fragment upward so that there is overriding of the two fragments, also the distal end of the proximal fragment is forced under and at times through the quadriceps muscle This displacement may be severe if the patient has fallen from a height Some lateral displacement of the upper fragment may also be present usually it is displaced inward resulting from the action of the adductor muscles Rarely, the direction of the responsible forces are such that the distal fragment assumes an anterior and the proximal a posterior position (Figs 286 and 287)

DIAGNOSIS OF FRACTURE AND SOFT TISSUE INJURY

As a rule diagnosis of a fracture of the distal end of the femur offers no difficulty There is always a history of severe violence followed by complete loss of function of the limb pain swelling in and around the knee and in many instances a visible deformity Abnormal motion at the fracture site is readily demonstrable and of course associated with severe pain Shortening of the femur may also be evident and in many instances palpation discloses the bone ends in the popliteal space and under the quadriceps muscle The severity of the fracture cannot be determined with accuracy by clinical examination except in cases of intercondylar fractures with wide separation of the condylar fragments, which can be brought together by lateral pressure, when the pressure is released they tend to spring away However, if the proximal fragment is wedged between the condylar fragments, floating of the fragments is not demonstrable but broadening of the condylar region of the femur is clearly evident. Roentgenographic studies reveal the nature of the fracture

Examination of the limb should be conducted gently without causing pain to the patient and without traumatizing further the soft tissues The neurovascular structures in the popliteal space are vulnerable to injury in the presence of a fracture in the supracondylar region Examination should include evaluation of the status of the structures in the popliteal space, impairment of the circulation of the limb and sensory and motor abnormalities indicate implication of the neurovascular structures A large pulsating hematoma in the posterior aspect of the knee points to rupture of the popliteal artery

MANAGEMENT

Most supracondylar fractures can be reduced by manipulative procedures, maintenance of the reduction is achieved by plaster fixation, continuous traction and, in rare instances internal fixation The author s choice of treatment is reduction by manipulation and fixation by a plaster spica If this fails, continuous traction is employed If both the above methods fail, open reduction and internal fixation is performed

Manipulation and Plaster Fixation. Reduction of a supracondylar fracture is

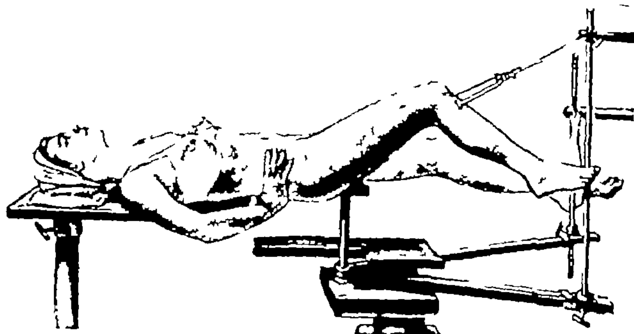


FIG 288 Method of making mechanical traction to reduce supracondylar fractures. The threaded wire is inserted, and the tautener is attached to the elevated foot piece of the table now mechanical traction can be applied readily to the flexed limb

difficult to attain by unaided manual manipulation it is achieved best with the patient on a fracture table and by the aid of skeletal traction, as described by Griswold and Wood Injection of 20 to 30 cc. of *1 or 2 per cent procaine solution into the* hematoma facilitates positioning of the pa*tient on the fracture table* While the patient is being moved from the bed or the carriage to the fracture table an assistant grasps the ankle and makes steady manual traction Then a general anesthesia is administered or a spinal anesthetic agent is used since complete muscular relaxation is essential in order to effect a satisfactory reduction The patient is now ready to be positioned on the fracture table While manual traction is maintained on the af*fected side* the patient is pulled down against the perineal post, which fits snugly against the ischium of the opposite side the foot of the sound limb is bound firmly to the footplate of the table

As a rule the joint cavity is distended with blood which must be aspirated under strict aseptic technic as described on page 498 After aspiration is completed the skin is carefully prepared the limb is draped and made ready for the insertion of a pin through the tibia immediately below the tibial tubercle The author prefers to use *threaded wires these take a firm grip on* the tibia and permit no motion between the *protruding ends of the wire and the soft* tissues hence the hazards of wound infection are reduced A small stab wound is made in the skin at the point of entrance and exit of the wire A drill holder that accommodates a Jacob chuck is employed to insert the threaded wire through the tibia Next a wire tautener is fixed to the wire and the manual traction is transferred to the spreader Now the stage is set to execute the maneuvers that will effect re*duction of the fracture*

An assistant makes steady continuous traction on the spreader in the line of the long axis of the femur at the same time the spreader is raised slowly in a vertical direction until the hip i flexed from 45 to 60 The lower leg with the foot in plantar flexion remains free By means of a stout

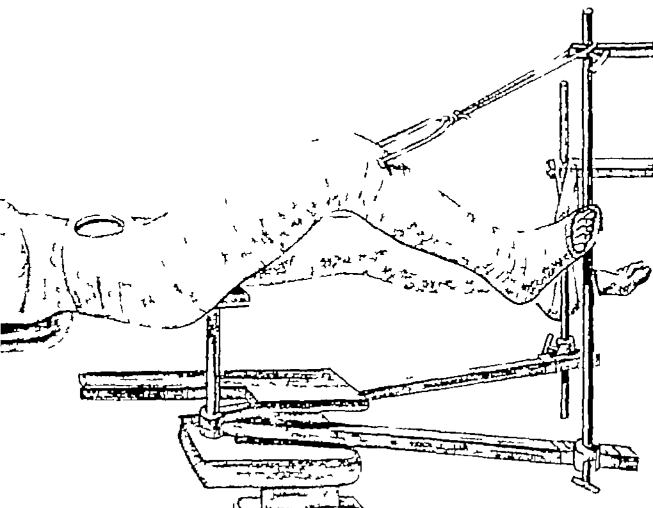


Fig 289 After reduction is achieved a plaster spica is applied holding the knee in flexion and incorporating the ends of the threaded wire.

cord, the spreader is attached to the elevated footpiece of the table (Fig 288) Mechanical traction is now made until normal length of the femur is restored usually, the free, flexed lower leg creates a downward force on the distal fragment sufficient to correct the deformity The operator may perfect the reduction by manipulation, forcing the lower end of the upper fragment downward and the proximal end of the distal fragment upward and correcting any medial displacement by lateral pressure. After length is restored and the deformity is corrected the traction is reduced slightly in order to permit engagement of the fragments The final position is checked by roentgenographic studies, and, if found to be satisfactory, a plaster spica is applied extending from the toes on the affected side to the costal margin, holding the knee in the flexed position necessary to maintain the reduction (Fig 289) The protruding ends of the threaded wire are incorporated in the plaster, mechanical traction is not released until the plaster is set Generally, the wire is removed at the end of 4 to 6 weeks, and the plaster spica at the end of 6 to 8 weeks

Treatment by Manipulation and Traction. Occasionally, supracondylar fractures are encountered in which it is impossible to maintain the reduction by plaster fixation This group comprises supracondylar fractures with severe comminution and those with fracture lines of such obliquity that the fragments cannot be engaged Continuous traction must be applied in order to ensure maintenance of the reduction, this

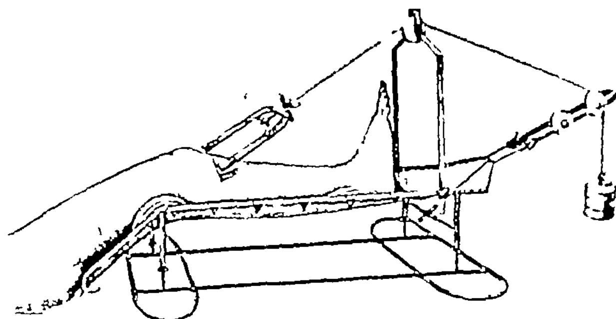


FIG 290 Position of patient in a Bohler Braun splint Note that the angle of the splint is behind the site of fracture and not at the knee joint A pad may be necessary to make pressure on the medial aspect of the lower end of the proximal fragment to overcome the pull of the adductor muscles and to correct a valgus deformity

is achieved best by skeletal traction Traction alone is not sufficient to restore anatomic reposition of the fragments manipulation is necessary to reduce the fracture and skeletal traction is employed to maintain the desired position until healing has progressed sufficiently to preclude redisplacement of the fragments The author has found the technic described by Smillie to be an efficacious method Essentially the fracture is reduced under anesthesia and continuous skeletal traction is made on a Böhler Braun splint the position of the limb in the splint is such that the angle of the splint is slightly behind the site of fracture and not at the knee joint (Fig 290)

TECHNIC Under general anesthesia a pin is inserted below the tibial tubercle here again the author employs a threaded wire for the reasons recorded previously then a wire tautener is attached to the pin While steady traction is made on the leg the patient is transferred to a fracture bed and the affected extremity is placed in a Bohler Braun splint which is attached firmly to the foot of the bed Reduction is achieved by the following method One assistant makes steady traction on the spreader in the line of the femur while a second assistant makes countertraction by pressing backward on the iliac crests After length of the femur has been restored the operator grasps the distal fragment with both hands and elevates it forward so that it assumes its normal relation to the upper fragment Then traction is reduced slightly to allow the fragments to engage and the extremity is adjusted to the splint Loss of position of the fragments is prevented by placing a large pad of soft wool or cotton immediately behind the distal fragment and by adjusting the limb to the splint so that the angle of the splint is behind the site of fracture (Fig 290) After reduction is achieved the direction of the traction force which tends to maintain the desired position of the fragments is determined and is

secured by adjusting the height of the pul ley Several attempts may be necessary be- fore satisfactory alignment of the frag ments is attained- roentgenographic control is essential in order to determine the true position of the fragments Once reduction is attained and the limb is adjusted to the splint as described previously, from 10 to 12 pounds of traction usually suffices to maintain the desired position countertrac tion is made by elevating the foot of the bed from 8 to 10 inches

Occasionally, a case is encountered in which manual traction fails to stretch the long muscles of the thigh sufficiently to per mit reduction of the fracture unless the normal length of the femur is restored, it is impossible to disengage the lower fragment Such cases are best treated by a preliminary period of skeletal traction from 20 to 25 pounds of traction is employed for 24 to 48 hours no pad is placed under the distal fragment As pointed out by Smillie, this procedure usually results in full length of the femur, and with the patient anesthe tized manipulative reduction is achieved readily From 10 to 12 pounds of traction now suffices to maintain the corrected position.

Postreduction Management. The trac tion apparatus and the position of the limb must be checked daily until healing has progressed sufficiently to ensure against re displacement of the fragments Even with continuous traction there is a tendency for the lower fragment to tilt backward and for a valgus angulation to develop at the level of the fracture For the first few days daily roentgenographic supervision is es- sential thereafter roentgenograms should be taken every 2 or 3 days until consolida tion has rendered the fracture stable Trac tion a pad of wool correctly placed be neath the lower fragment and maintenance of the angle of the splint at the level of the fracture site all tend to prevent backward tilting of the lower fragment If the pull of the adductor muscles is strong enough to produce a valgus deformity, the angulation can be corrected by a pad's making pressure on the medial aspect of the lower end of the proximal fragment, a Cole type pres- sure pad serves this purpose well Through out the period of immobilization the soft tissues of the limb particularly on the posterior aspect of the knee, should be inspected constantly in order to prevent pressure areas Repeated adjustments and replacements of the wool roll may be neces- sary If the pad becomes compressed and firm, it is apt to produce necrosis of the skin or paralysis of the lateral popliteal nerve.

Immobilization of the limb in the flexed position favors rapid and pronounced loss of quadriceps tone and volume, moreover the flexed position precludes execution of effective exercises designed to restore maxi mum function and power Powerful con tractions of the vastus medialis are possible only in the last 10° of extension Hence, it becomes apparent that the flexed position must be maintained no longer than is neces- sary to preclude redisplacement of the frag ments As a rule, most supracondylar frac tures exhibit sufficient consolidation in 4 to 6 weeks to permit reduction of the amount of flexion, this is determined by clinical and roentgenographic study When this stage of healing has been reached, the skele- tal traction is replaced by adhesive traction to the lower leg and the limb is placed in balanced suspension in a Thomas splint with a Pearson attachment the bulk of the padding under the knee is gradually re duced to allow increasing extension at the knee joint. This apparatus permits the pa tient to exercise effectively the quadriceps, especially the vastus medialis and also to commence mild knee flexion exercises Quadriceps setting exercises should be per formed while the patient is in skeletal trac tion these tend to keep the patella free and in a measure allay formation of adhe sions All exercises should be performed on a regulated regimen, every hour on the

hour under supervision if possible, and always executed within the patient s tolerance without being prejudicial to the stability of the fracture As consolidation increases the exercises are intensified Daily physical therapy in the form of radiant heat and massage to muscles of the thigh and the calf is beneficial Depending upon the rapidity of restoration of function in the knee joint the limb is maintained and exercised in the balanced suspension apparatus for 2 to 4 weeks When complete and powerful extension is achieved and clinical and roentgenographic studies have disclosed firm consolidation of the fracture, protected weight bearing is commenced using a Thomas walking caliper splint. The caliper is worn until the supportive structures of the knee especially the quadriceps are strong enough to provide adequate stability for the knee joint and a solid bony union of the fracture is demonstrable in the roentgenograms. As a rule this period is from 6 to 12 weeks

Regardless of the method of fixation after reduction whether it is a plaster spica or traction the patient as a whole in addition to the affected limb must be considered If the patient is in plaster, active setting exercises of the quadriceps and the hamstrings of the affected limb should be commenced early and performed regularly every hour by the clock starting with 5-minute periods which are increased gradually as power and control are restored to the muscles in question In a similar manner muscles about the hip and the ankle are exercised actively The unaffected limb and the upper extremities also should be put through a daily course of supervised active exercises this not only improves the tone of the muscular system and maintains normal joint function of the unaffected parts but it also improves the patient s morale Patients in traction are treated in a similar manner because these patients enjoy greater freedom than those in plaster the general body exercises and those performed by the injured limb

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factors also tend to prolong the immobilization period and result in some degree of permanent dysfunction If the fragments heal with some backward angulation or valgus deformity the normal mechanics of the knee are altered A recurvatum deformity at the knee joint following malunion of a supracondylar fracture presents difficult problems, the stability of the joint is jeopardized, and the quadriceps is lengthened and weakened Correction in cases producing severe impairment of function may be attained by a supracondylar osteotomy, the subsequent immobilization period may result in further loss of motion at the knee joint. Both the surgeon and the patient must be prepared to accept this hazard before the operation is performed Valgus deformities predispose the joint per se to abnormal stresses which invariably lead to the formation of varying degrees of degenerative arthritis. If the deformity is severe and correction by osteotomy is desirable, the same considerations noted above for correction of recurvatum deformities are applicable to correction of valgus deformities Incongruity of the articular surfaces of the femur, the tibia and the patella following supracondylar or intercondylar fractures is another important factor responsible for the development of degenerative arthritis All the above considerations must be taken into account when an attempt is made to anticipate the prognosis in cases of supracondylar or intercondylar fractures. For practical purposes, maximum restoration of function is obtained in 6 to 12 months, provided that the lesions are managed correctly

Open Reduction. Uncomplicated supracondylar fractures rarely necessitate open procedures to effect reduction, however, in rare instances the conservative methods described previously fail Under such circumstances the fragments are exposed and realigned under direct vision Some form of internal fixation is usually employed The

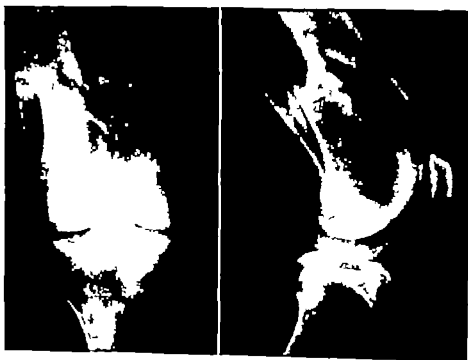


Fig 291 Intercondylar fracture of the femur Note the severe comminution and the posterior displacement of the distal condylar fragments. The sharp fragments projecting into the popliteal space jeopardize the vessels in this region The patient was treated adequately by the closed method described herein

hour under *supervision if possible*, and always executed within the patient's tolerance without being prejudicial to the stability of the fracture As consolidation increases, the exercises are intensified. Daily physical therapy *in the form of radiant heat* and massage to muscles of the thigh and the calf is beneficial Depending upon the rapidity of restoration of function in the knee joint, the limb is maintained and exercised in the balanced *suspension apparatus for 2 to 4 weeks* When complete and powerful extension is achieved and clinical and roentgenographic studies have disclosed firm consolidation of the fracture protected weight bearing *is commenced, using a* Thomas walking caliper splint The caliper is worn until the supportive structures of the knee, especially the quadriceps are strong enough to provide adequate stability *for the knee joint and a solid, bony union* of the fracture is demonstrable in the roentgenograms. As a rule this period is from 6 to 12 weeks

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The rapidity of restoration of function and the extent of the residual disability are *governed* by *several factors these comprise* the age and the general physical condition of the patient, the severity of the osseous and the soft tissue lesions implication of the intra-articular surfaces of the femur the *ultimate position of the fragments* after healing the length of immobilization and the co-operation of the patient In the older age groups the powers of osteogenesis may be greatly diminished when compared with younger age groups hence bone healing is slow and immobilization must be maintained for longer periods This favors formation of intra articular adhesions and atrophy and fibrosis of the muscles of the thigh. It becomes apparent that under such conditions varying degrees of residual dysfunction must be anticipated Severely comminuted fractures of *the supracondylar* region are generally associated with extensive soft tissue damage particularly to the extensor mechanism and the suprapatellar pouch massive hemarthrosis is the rule in these cases Such *fractures* usually heal slowly and the reparative *process* in the soft tissues may terminate in the *formation* of numerous adhesions and *fibrosis and loss* of power of the implicated muscles these

factors also tend to prolong the immobilization period and result in some degree of permanent dysfunction If the fragments heal with some backward angulation or valgus deformity, the normal mechanics of the knee are altered. A recurvatum deformity at the knee joint following malunion of a supracondylar fracture presents difficult problems, the stability of the joint is jeopardized, and the quadriceps is lengthened and weakened Correction in cases producing severe impairment of function may be attained by a supracondylar osteotomy the subsequent immobilization period may result in further loss of motion at the knee joint Both the surgeon and the patient must be prepared to accept this hazard before the operation is performed Valgus deformities predispose the joint per se to abnormal stresses which invariably lead to the formation of varying degrees of degenerative arthritis If the deformity is severe and correction by osteotomy is desirable the same considerations noted above for correction of recurvatum deformities are applicable to correction of valgus deformities Incongruity of the articular surfaces of the femur, the tibia and the patella following supracondylar or intercondylar fractures is another important factor responsible for the development of degenerative arthritis All the above considerations must be taken into account when an attempt is made to anticipate the prognosis in cases of supracondylar or intercondylar fractures. For practical purposes, maximum restoration of function is obtained in 6 to 12 months, provided that the lesions are managed correctly

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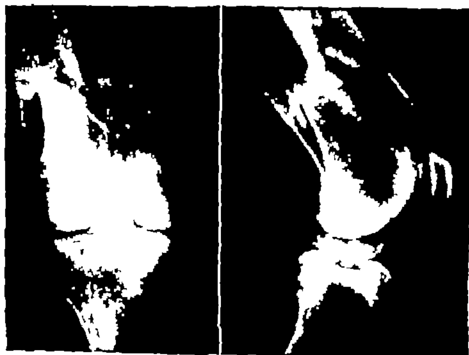


FIG 291 Intercondylar fracture of the femur Note the severe comminution and the posterior displacement of the distal condylar fragments The sharp fragments projecting into the popliteal space jeopardize the vessels in this region The patient was treated adequately by the closed method described herein

technic and the postoperative management are similar to the procedures employed for intercondylar fractures treated by open methods.

Intercondylar Fractures (T and Y Fractures)

The mechanisms producing these fractures are the same as those producing supracondylar fractures except that as a rule the violence is more severe fractures implicating the condyles are relatively uncommon The soft tissue injuries are extensive particularly the damage sustained by the suprapatellar pouch and the extensor mechanism hemorrhage into the joint cavity is always massive The major fractures comprise a break in the supracondylar region which is usually roughly transverse and one or several vertical splits through the condyles producing the classical T or Y fractures (Fig 291) Severe comminuation of the supracondylar region may be present making the fracture extremely unstable and also increasing the difficulty of attaining and maintaining reduction The position of the fragments is governed by the direction of the fracturing forces and by muscle pull Not infrequently the lower end of the proximal fragment is driven into the cancellous bone of the condylar region acting like a wedge between the two condyles

Management

Before definitive treatment is instituted the joint is aspirated if after reduction of the fracture hemarthrosis has recurred aspiration should be repeated Essentially treatment of intercondylar fractures is the same as that described for supracondylar fractures except that in addition to restoring normal alignment between the condylar region and the shaft of the femur the condyles must be restored to their normal anatomic position in relation to each other and to the articular surfaces of the tibia This last feature is of first importance since surface in a weight bearing joint su the knee will lead inevitably to degene alterations and pronounced disability

The author prefers to reduce these tures by skeletal traction and the man tive maneuvers described for reducti the supracondylar fractures reducti maintained by continuous traction the length of the femur and the norm lation between the condyles and the are restored next while an assistant n steady traction the condyles are replac relation to each other by lateral com sion If manual compression fails to ac the desired position, a screw clamp su that recommended by Böhler, Forrest Scudder may be employed The sides c condyles are protected by a layer of the clamp is applied and tightened qui and the fragments are squeezed into tion. Then the pressure is released qu to avoid necrosis of the skin and the u lying soft tissues It is important that forward or backward tilting of one o condyles be corrected usually this ca achieved manually A rough estimate o amount of compression to make may b termined by applying the clamp to ound knee and measuring the distance tween the faces of the clamp If the r genograms show satisfactory repositic of the fragments the limb is adjusted t Böhler Braun splint and from 10 t pounds of traction is applied to the le

The postreduction management is si in every feature to that recorded for supracondylar fractures. In some insta in order to maintain the desired positio the fragments the knee must be in the tended position Under such circumsta a Thomas splint is employed however Pearson attachment is added later w healing has progressed sufficiently to a flexing exercises at the knee joint

Reduction and Fixation by Surg Intervention Open reduction is justifie cases in which the aforementioned conse

tioning of the fragments A common cause for failure is severe comminution of the supracondylar region with displacement and rotation of some of the small bony fragments which are wedged between the major condylar fragments, holding them apart (Fig 292) This is usually determined at the time that closed manipulative reduction is attempted Occasionally, subsequent roentgenographic studies of a fracture reveal that the redisplacement of the fragments has occurred in spite of adequate continuous traction, such an event is an indication for surgical intervention When reduction under direct vision becomes necessary, following failure to achieve a satisfactory manipulative reduction, the patient is transferred to a fracture table the pin is left in the tibia. When operation is performed because of subsequent redisplacements of the fragments, the patient is taken out of the traction apparatus and placed on the fracture table during the transference an assistant makes steady traction on the yoke attached to the pin in the tibia. The pin is not removed, it is covered with sterile drapes which also envelop the lower leg This permits the surgeon to use the pin for traction and to flex and extend the leg during the operation

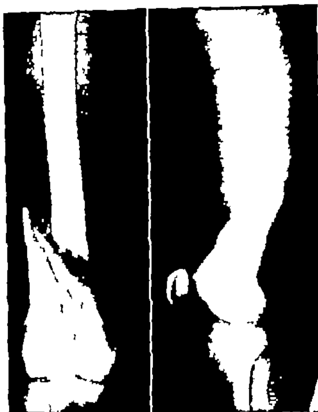


Fig 292 Intercondylar fracture of the femur with gross comminution Observe the long pointed fragment wedged between the proximal and the distal fragments, this piece of bone prevented adequate correction Reduction was achieved by open methods similar to that depicted in Figure 294 C

Technic The fracture site is exposed through an anterolateral incision between the rectus femoris and the vastus lateralis, the vastus intermedius is divided parallel with the longitudinal axis of the femur The distal end of the incision extends slightly below the joint line and then curves gently anteriorly it divides the lateral aponeurotic expansion of the quadriceps and the joint capsule bringing into view the intra articular portion of the femur By subperiosteal dissection the distal third of the femur and the fracture site are exposed if possible the suprapatellar pouch should be stripped from the bone fragments without laceration since an attempt should be made to restore the pouch after the reduction of the fragments is achieved At this point a careful inspection of the joint is made, and the extent and the nature of the fracture are determined All blood clots and loose fragments of bone are flushed out of the wound and the supracondylar region with normal saline solution Attention is first directed to the condylar fragments they are restored to their normal anatomic relation to each other and secured by threaded pins inserted through stab wounds made posterior to the incision then the pins are cut below the level of the skin so that they are readily accessible when the time arrives to remove them Some surgeons use long screws, bolts or blade plates for fixation of the condylar fragments Now the fracture is converted from an intercondylar to a supracondylar fracture next, the proximal and the distal

fragments are approximated (Fig 293) In some instances after reduction of the supra condylar fracture, the stability of the reduction is such that no additional internal fixation is required In others the reduction is not stable, and further fixation is essen tial Under these circumstances the author prefers to use two Rush nails one is passed through each condyle and into the medullary canal of the proximal fragment (Fig 294 C) These provide adequate stability and tend to prevent angulation at the fracture site In the event that there is severe comminution of the supracondylar region more rigid fixation is desired in order to ensure adequate contact between the distal end of the upper fragment and the proximal end of the lower fragment This is achieved best by a blade plate, preferably one that con forms to the lateral surface of the condyle of the femur It is important to emphasize that the condylar fragments must be fixed firmly by one of the methods noted pre viously before the blade is driven home because the blade tends to separate them. If a blade plate is used it should be placed subsynovially and subperiosteally in order to preclude unfavorable joint reactions

After satisfactory reduction and stability of the fracture are attained the wound and the joint cavity are flushed again with nor mal saline solution and the edges of the suprapatellar pouch are approximated with fine cotton sutures Then the wound is closed in layers and the limb is immobilized in a plaster spica incorporating the threaded wire through the tibia the spica extends from the toes to the lower margins of the costal cage As a rule after 3 to 5 weeks the spica can be removed and the limb

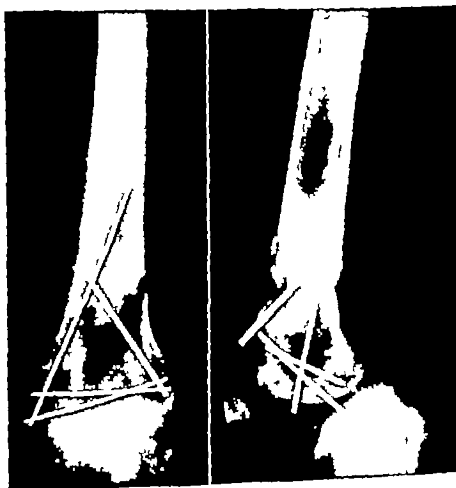


Fig 293 Fixation of severely comminuted Y fracture by pins

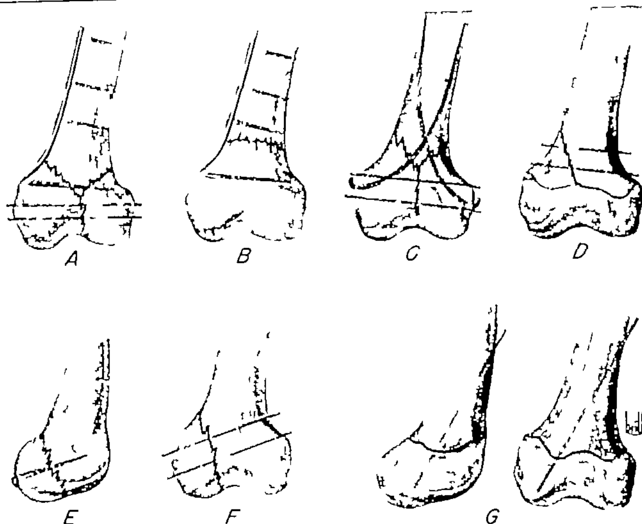


FIG 294 Different methods of internal fixation for condylar and intercondylar fractures of the femur (A) Y fracture fixed by a Blount blade plate and 2 threaded wires (B) Supracondylar fracture fixed by a Blount blade plate. (C) Comminuted intercondylar fracture fixed with a threaded wire and 2 Rush nails (D) Separation of the epiphysis, including a triangular segment of the metaphysis fixed by 2 threaded wires. (E) Vertical fracture of the posterior position of one of the femoral condyles fixed by a single screw (F) Fracture of a single condyle fixed by 2 threaded wires (screws may be used) (G) Separation of the femoral epiphysis immobilized by a single wire, this is permissible if closed methods fail to maintain the reduction

placed in balanced suspension without jeopardizing the position of the fragment. From this point on the treatment is similar in every feature to that described for supra condylar fractures. If threaded wires are employed, they are removed at the end of 4 to 6 weeks under local anesthesia through small stab wounds made immediately over the pins which are readily palpable under the skin The time of withdrawal of the pins usually corresponds to the time of removal of the plaster spica.

Fracture of a Single Condyle of the Femur

The mechanisms responsible for this fracture are essentially those producing fractures of the corresponding tibial condyles The lesions usually result from direct violence to the side of the knee forcing the joint into valgus or varus producing a fracture of the lateral or the medial condyle (Fig 295) Generally, the fracture line is vertical and in the sagittal plane, if the

force is applied with the knee slightly flexed the fracture line may be roughly transverse in an oblique anteroposterior plane rarely, the forces are applied to the knee in moderate flexion splitting off the posterior portion of the condyle in the frontal plane In most instances displacement of the fragments is not marked since the tibia retains its normal anatomic position in relation to the opposite sound femoral condyle and the collateral ligament and the capsule on the affected side usually



Fig 295 Fracture of the medial femoral condyle The line of fracture is roughly in the vertical and sagittal plane the condylar fragment is tilted slightly posteriorly



Fig 296 The reduced fragment in Figure 295 is immobilized by 2 screws



FIG 297 Method of reduction of fracture of the lateral femoral condyle. Traction is made in a lateral direction, after reduction, while traction is maintained a plaster spica is applied, holding the knee in a position of varus

remain intact and tend to prevent marked separation of the fragment Of course this is not true of the fractures in the frontal plane implicating the extreme posterior portion of the condyles, these fragments may not be controlled by ligamentous attachments and the degree of separation is governed by the severity of the fracturing force the fragments may be displaced as a free body into the joint cavity Because the knee joint is forced into varying degrees of abduction or adduction at the time of the injury the contralateral collateral ligaments are invariably stretched or torn partially or completely The intra articular nature of the fracture is responsible for the massive hemarthrosis always present

Management. Correct treatment of these fractures is governed by the knowledge that restoration of the fragments to their anatomic position in relation to the intact femoral condyle and the tibial plateau is most essential in order to avoid incongruity of the articular surfaces and preclude degenerative alterations which are inevitable in a malaligned intra-articular fracture in a weight-bearing joint. Also loose small fragments of bone must be removed

CONDYLAR FRACTURES IN THE SAGITTAL PLANE

In this type of fracture the fragment is displaced upward and may be tilted posteriorly (Fig 295) Before reduction is performed, the condition of the contralateral collateral ligament must be determined, if ruptured completely, the ligament must be repaired and the fragment reduced and fixed under direct vision. The methods of repair of the ligaments are described in Chapter 8 Traumatic Lesions of the Ligaments' The fracture site is exposed through a medial or lateral incision depending on whether the medial or the lateral condyle is involved the fragment is levered into position and secured by screws or threaded pins (Fig 296) A plaster spica is applied from the costal cage to the toes After 4 to 5 weeks the pins and the cast are removed the limb is placed in balanced suspension and quadriceps and flexing exercises of the knee joint are instituted This apparatus is discarded after 10 to 14 days and the patient is allowed up on crutches Weight bearing is permitted at the end of 10 to 12 weeks depending on the severity of the lesion and the progress of osseous union demonstrable by roentgenographic study

If the continuity of the contralateral collateral ligament is not broken the fracture is reduced by traction and manipulation The intact collateral ligament on the affected side is used to pull the fragment downward into position Manipulation corrects any posterior or anterior tilt of the fragment This method is executed best on a fracture table The patient's feet are fastened to the foot plates and moderate mechanical traction is made on the affected side After the knee joint is aspirated a 4 inch strip of muslin bandage is passed around the knee joint and an assistant makes steady traction in a medial or lateral direction depending on the condyle involved For a fracture of the lateral condyle traction is in the lateral direction producing genu varus for a fracture of the medial condyle, traction is in the medial direction producing genu valgus (Fig 297) Any displacement of the fragment in the anteroposterior plane is corrected manually If traction and manual compression fail to approximate the condyles a screw clamp i employed While lateral or medial traction is maintained a plaster spica is applied from the costal cage to the toes the plaster is molded and compressed uniformly around the condyles to maintain the corrected position The cast is removed after 4 or 5 weeks and the extremity is placed in balanced suspension From this point the treatment is similar to that described above As an alternative to plaster fixation reduction may be maintained by continuous skeletal traction with 10 to 12 pounds, using a threaded wire below the tibial tubercle This is achieved best with the extremity in a Thomas splint with a Pearson attachment or in a Böhler Braun splint Any persisting medial or lateral angulation of the knee is corrected by a Cole type of pressure pad applied to the lower third of the femur on the side opposite the fracture

Occasionally it is impossible to attain satisfactory realignment of the fragments by closed methods If such is the case open reduction and fixation as described previously is justified (Fig 294 F)

CONDYLAR FRACTURES IN THE FRONTAL PLANE

Fortunately this type of condylar fracture is rare When the fragment is relatively large it may be reduced by traction and manipulation reduction is maintained by the same methods as those described for fractures in the sagittal plane Occasionally the fragment may be displaced and rotated backward so that manipulative method combined with traction fail to obtain anatomic reposition of the fragments Such fractures are reduced by open methods The fracture site is exposed through a posterior incision (medial or lateral depending on the condyle involved) the fragment is

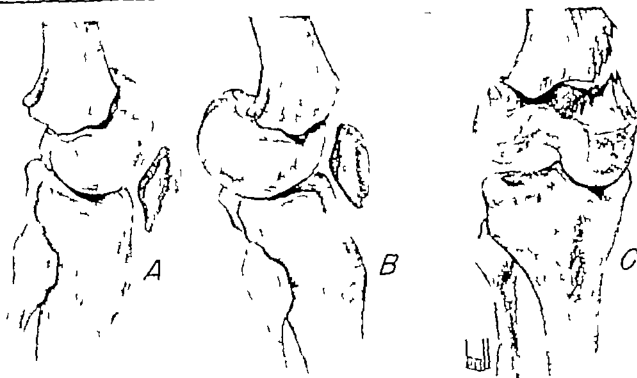


FIG 298 Types of displacement of the lower femoral epiphysis. (A) The epiphysis is displaced forward B is rare type the epiphysis is displaced backward and tilted toward the popliteal fossa. (C) The epiphysis is displaced lateralward

levered into its normal position and made secure by a screw (Fig 294 E) Subsequent treatment is the same as that described for sagittal fractures Small completely detached fragments of the posterior portion of the femoral condyles are removed.

SEPARATION OF DISTAL EPIPHYSIS OF THE FEMUR

Traumatic separation of the lower epiphysis of the femur is a relatively rare lesion usually occurring in boys between 8 and 14 years of age Most cases are the result of violent hyperextension or torsion injuries, but some are produced by direct violence The heads of origin of the gastrocnemius muscle, the posterior capsule and the reinforcing ligaments shear the epiphysis off the diaphysis and displace it to an anterior position The distal fragment may comprise the entire lower epiphysis or it may comprise the epiphysis and a triangular portion of the metaphysis

The epiphysis is usually displaced anteriorly and upward so that it lies on the anterior surface of the diaphysis, the degree of separation varies, in some it is incomplete, in others it is complete (Fig 298) In cases of complete separation, the distal end of the shaft of the femur protrudes into the popliteal space, jeopardizing the neurovascular structures In rare instances depending on the direction of the fracturing force, the epiphysis is displaced backward and tilted toward the popliteal fossa or it may be displaced laterally (Fig 298) Posterior displacement of the distal end of the shaft or, in the reverse deformity, backward displacement of the lower epiphysis, may compress or inflict serious injury to the vessels and the nerves in the popliteal space (Fig 299) Should examination of the extremity reveal any impairment of its circulation, immediate reduction is imperative Evidence of laceration or rupture of the vessels is an indication for immediate surgical exploration of the popliteal region Cyanosis and coldness of the leg absence of pulsation in the dorsalis pedis and anterior tibial



FIG 299 (*Left*) Complete separation of the distal femoral epiphysis showing typical deformity In this case (B R. female aged 9), a satisfactory reduction could not be attained by closed methods. (*Right*) Reduction was achieved by open operation the epiphysis was immobilized by transfixing the lower end of the femoral shaft and the epiphysis with a wire.

vessels are findings pointing to vascular impairment of the limb

MANAGEMENT

In all instances replacement of the epiphysis must be performed without delay A few days of procrastination not only jeopardizes the vessels in the popliteal space but also renders the reduction difficult because the reparative process in the first two decades of life is unusually active

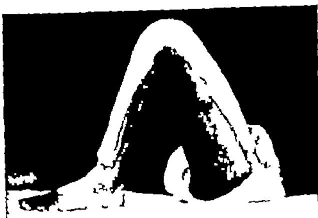
Reduction in all instances should be performed under general anesthesia in order to obtain complete muscular relaxation the manipulative maneuvers and subsequent fixation of the extremity in plaster are facilitated if a fracture table is used After the patient is placed on the table and receives a general anesthetic agent the foot of the unaffected limb is fastened to the foot plate Under aseptic technic, the involved knee joint is aspirated before reduction is executed When the lower epiphysis is displaced anteriorly reduction is accomplished by grasping the lower leg with the knee flexed from 30 to 45° and making strong manual traction in the long axis of the thigh This maneuver disengages the fragments reduction is completed by pulling the epiphysis downward over the lower end of the shaft and at the same time the knee is flexed to 90° As this last step is executed an assistant elevates the proximal fragment by making upward pressure on the under surface of the lower end of the thigh Occasionally the knee must be flexed beyond a right angle to obtain the desired reduction However the degree of flexion maintained when the limb is immobilized in plaster depends upon the amount of swelling in the posterior aspect of the knee and the status of the circulation of the limb Any lateral displacement of the epiphysis is corrected by pressure on the shaft and the epiphysis in opposite directions this is an important step in order to avoid any varus or valgus deformity at the knee joint The final position is checked by roentgenograms If the reduction is satisfactory the extremity is immobilized by a long anterior plaster

splint, extending from the groin to the ankle joint, holding the knee acutely flexed, the position of the plaster splint is ensured by plaster bandages passed around the calf and the thigh (Fig 300) The popliteal space must be protected by adequate padding and the circulation of the leg must be checked carefully at regular intervals until it is certain that the circulation of the limb is out of danger

As a rule after 3 to 4 weeks the original plaster splint can be removed, flexion is decreased to 30° to 45°, and a new plaster splint is applied The new position in flexion is governed by the progress of the healing process determined by clinical and roentgenographic examination. Care must be taken not to decrease flexion too rapidly, because redisplacement of the epiphysis may occur The second plaster splint is removed at the end of 3 or 4 weeks at this time consolidation is sufficient to allow unrestricted motion at the knee joint Exercises are commenced to restore quadriceps power and joint motion. When complete extension of the joint is attained, protected weight bearing on crutches is permitted, unprotected weight bearing is allowed when the quadriceps apparatus has regained sufficient power to stabilize the knee joint adequately and to protect it from abnormal stresses incident to joint function

Posterior displacements of the epiphysis are reduced by traction to restore length of the femur followed by forward displacement of the epiphysis to restore its anatomic position and extension of the knee to retain the corrected position A plaster cast is applied extending from the costal cage to the toes this is retained for 6 to 8 weeks depending upon the progress of consolidation at the site of separation

Management of Irreducible Distal Femoral Epiphyseal Separations. Occasionally cases are encountered in which sufficient time has elapsed since the injury before treatment is instituted to allow some union between the epiphysis and the anterior surface of the femur In such cases the manipulative methods described above may fail, necessitating more radical methods The author has employed the method described by Griswold and Wood in two cases and has succeeded in getting an adequate reduction in both This method is reserved for cases in which there is no clinical evidence of injury to the neurovascular structures in the popliteal fossa requiring exploration of this region A Steinmann pin is passed through the upper third of the tibia (the author prefers to use threaded pins and a spreader) Care must be taken not to injure the proximal epiphyseal plate of the tibia. The patient is placed in a fracture bed and the hip of the affected side is flexed 90° From 25 to 30 pounds of traction is applied to the pin in a vertical direction. Generally after 24 to 48 hours of traction the fragments are disengaged suffi



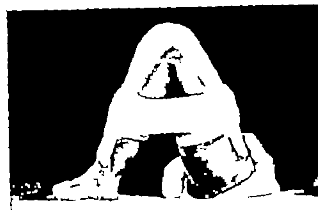


Fig 300 Type of immobilization of limb after reduction of lower femoral epiphysis.

ciently to allow an attempt at reduction by the manipulative methods described previously this is performed under general anesthesia. After reduction is achieved the post reduction management is similar in every feature to that described for recent and reducible separations of the femoral epiphysis

Although adequate repositioning of the epiphysis is desirable and should be the goal of every reduction, occasionally this cannot be achieved by manipulative methods One must remember that the initial violence inflicts severe injury to the epiphyseal plate and disrupts in varying degrees the blood supply to the epiphysis Repeated unsuccessful manipulations and surgical procedures jeopardize further the normal growth of the epiphysis and may enhance processes leading to bizarre growth disturbances premature closure or even aseptic necrosis of the epiphysis It has been estimated that under the most favorable conditions approximately one third of these cases exhibit some alteration in the subsequent growth of the epiphysis (Fig 301) On the other hand clinical experience reveals that in many instances some displacement of the epiphysis is tolerated well especially by children who still have several *years before full skeletal growth is achieved* In infants and very young children there is an inherent tendency to re-establish normal alignment of the displaced epiphysis durin the subsequent years of growth this tendency is less evident in adolescence Hence in young children if accurate replacement of the epiphysis is not possible by closed methods some displacement may be accepted if it does not exceed more than one third the total detached surface of the epiphysis In the event that gross displacement of the epiphysis persists in spite of the methods described above then surgical intervention and replacement under direct vision are justifiable These principles are also applicable to acute cases in which manipulative reduction fails (Fig 299)

In the event that one must resort to open methods in recent or late cases the operation should be performed with the minimal amount of trauma. Periosteal and capsular stripping should be avoided as much as pos-

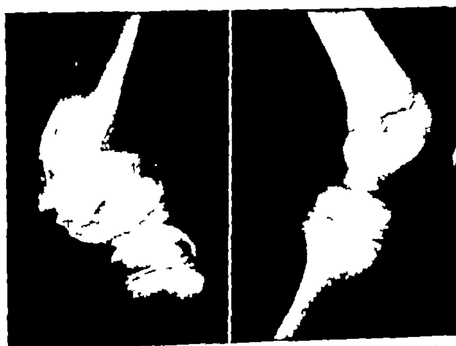


Fig 301 (*Left*) Growth disturbance of distal end of femur following separation of the lower femoral epiphysis (*Right*) Normal right limb used for comparison

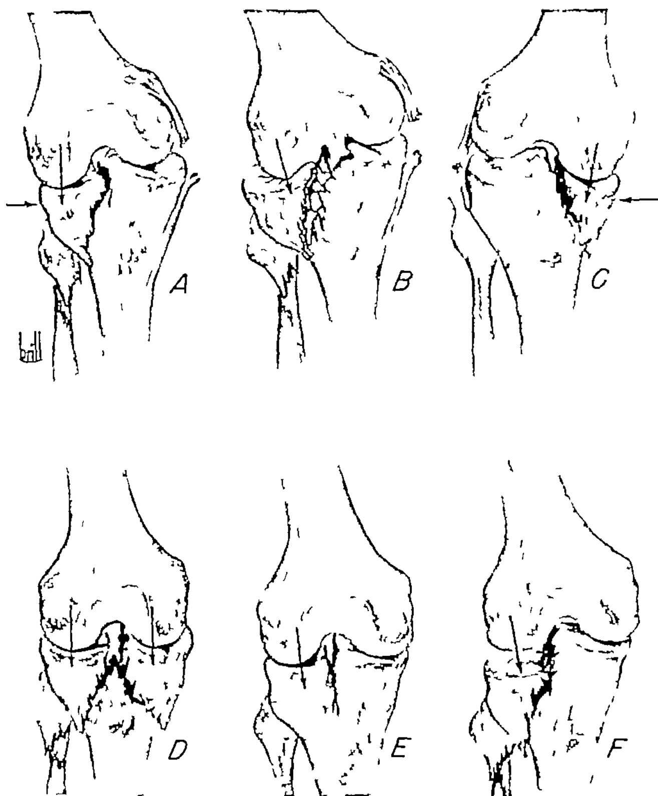


FIG 302 Mechanisms and types of fractures of the upper end of the tibia Severe abduction of the knee forces the lateral femoral condyle downward and inward Depending on the force different types of fractures of the lateral condyle of the tibia ensue (A) Oblique fracture with minimal or no displacement. (B) Wide separation and depression of the condylar fragments with comminution and impaction of the central portion of the lateral tibial plateau (C) Adduction forces produce similar fractures of the medial tibial condyle. (D) When the vertical force predominates, Y or T fractures are sustained (E) With minimal abduction or adduction in addition to the major downward force fractures such as that shown are sustained (F) With more abduction or adduction marked downward displacement of the corresponding tibial condyle occurs.

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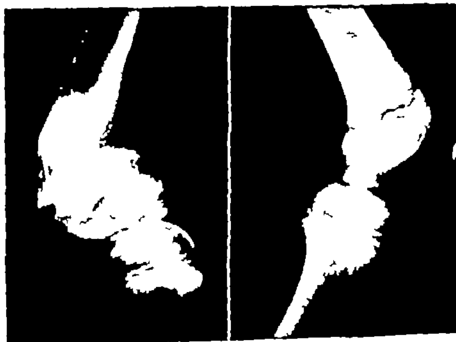


Fig 301 *(Left)* Growth disturbance of distal end of femur following separation of the lower femoral epiphysis *(Right)* Normal right limb used for comparison

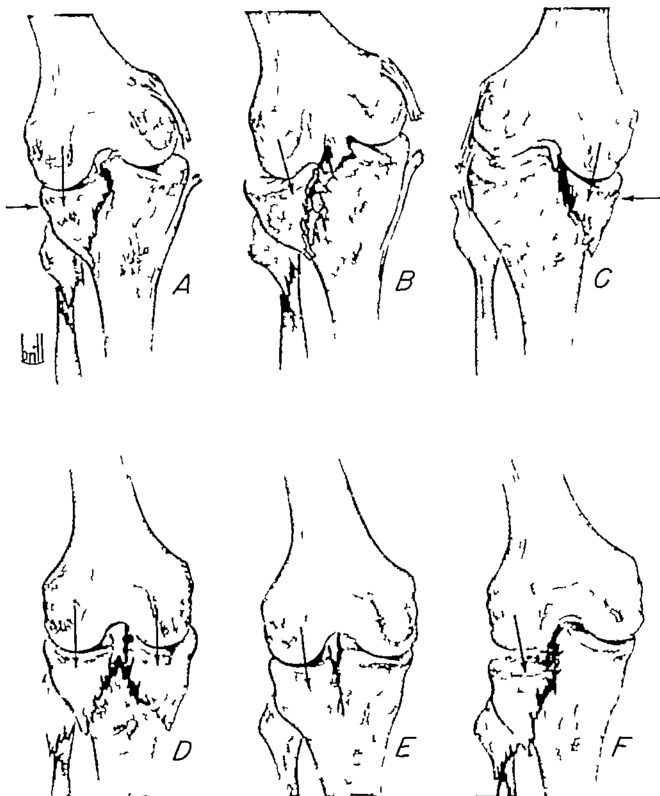


FIG 302 Mechanisms and types of fractures of the upper end of the tibia Severe abduction of the knee forces the lateral femoral condyle downward and inward Depending on the force different types of fractures of the lateral condyle of the tibia ensue (A) Oblique fracture with minimal or no displacement. (B) Wide separation and depression of the condylar fragments with comminution and impaction of the central portion of the lateral tibial plateau. (C) Adduction forces produce similar fractures of the medial tibial condyle (D) When the vertical force predominates, Y or T fractures are sustained (E) With minimal abduction or adduction in addition to the major downward force, fractures such as that shown are sustained (F) With more abduction or adduction marked downward displacement of the corresponding tibial condyle occurs

sible in order to preserve the blood supply to the epiphysis care should be taken to avoid crushing the epiphyseal plate or traumatizing the epiphysis per se If possible the reduction should be performed by manipulative maneuvers and not by levering the fragments into place by instruments foreign materials should not be used for internal fixation unless this is unavoidable Case B R is an example of an epiphyseal separation that could not be retained without some form of internal fixation (Fig 299) If internal fixation must be used a fine threaded wire transfixing the two fragments, provides sufficient stability until adequate consolidation occurs

The parents should be made aware of the unpredictable long term end results in both recent and old cases. Throughout the entire growth period roentgenographic studies should be made at regular intervals preferably every 6 months Shortening of the limb because of premature closure of the epiphyseal plate may be balanced by epiphysiodesis of the normal side at the appropriate time Partial closures may result in varying degrees of varus or valgus deformities before cessation of growth correction may be attained by stapling the open portions of the epiphysis after skeletal growth is complete correction may be effected by osteotomy In addition to deformities in the coronal plane of the knee joint such as valgus and varus deformities partial closures may produce deformities in the sagittal plane the methods of correction are similar to those described above (Fig 301)

FRACTURES OF THE UPPER END OF THE TIBIA

The configuration of the bony architecture of the upper end of the tibia are responsible for the frequency of fractures of this region Essentially the upper end of the tibia comprises two large overhanging bony eminences the lateral and the medial condyles which are composed of cancellous bone the lateral margins are buttressed by their cortical bone which is continuous with the shaft of the tibia. The cortical layer of bone spanning the interval between the lateral margins of the condyles and the shaft of the tibia is a weak connecting link and particularly in adults is responsible for the high incidence of fractures that implicate the condylar regions of the tibia

Mechanism and Associated Lesions of Condylar Fractures of the Tibia

Two mechanisms are *primarily responsible* for these lesions (1) violent abduction or adduction of the knee joint produced by forces applied to the outer and the inner aspects of the extremity and (2) by forces acting in a vertical direction on the tibial plateaus such as forces produced by falls on the feet (Fig 302) In many instances both mechanisms are acting in some degree however the ultimate type of fracture produced depends upon the force that is predominant In addition to the above mechanisms, fractures of the upper end of the tibia may result from severe direct violence such as direct impacts or crushing injuries A relatively common mode of direct violence is striking the upper end of the tibia by an automobile bumper (bumper fracture) Indirect violence that forces the knee in abduction or adduction generally produces fractures of a single condyle The abduction mechanism is by far the most common resulting in injuries of the tibial collateral and the cruciate ligaments varying from a strain to complete rupture The lateral condyle of the femur is forced downward and inward the amount of lateral and downward displacement of the tibial condyle is governed by the severity of the forces expended The types of fractures of the lateral condyle vary The lesion may comprise a vertical split in the condyle with minimal displacement on the other hand the condyle may be widely separated and depressed if a severe compressing force is also acting marked comminution and im-

paction of the central portion of the lateral tibial plateau may result, and, frequently fracture of the neck of the fibula is a concomitant lesion Often this same abduction mechanism is responsible for laceration and crushing of the lateral meniscus, which may be projected into the joint cavity or may come to lie between the bony fragments.

In falls from a height the predominant acting force may be one acting vertically downward If the lateral side of the joint sustains the brunt of the force the lateral femoral condyle drives the lateral tibial tuberosity directly downward with minimal or no fragmentation of its articular surface if the force is applied to the medial side of the joint, the same type of fracture of the medial tibial tuberosity ensues (however this lesion is rare) If, in addition to a violent compression force, moderate abduction of the knee occurs, the lateral tuberosity as a whole or in part depending upon the extent of abduction, is driven downward and outward however, again the degree of implication of the articular surface is minimal when compared with the disruption of the plateau that occurs when the predominant force is one of abduction Falling from a height and landing on the feet may result in fracture of both condyles the condyles may be driven downward and away from the shaft producing the Y or the T fractures Injuries resulting from direct violence may produce severe comminution of the upper end of the tibia or may produce a roughly transverse fracture at the level of the juncture of the tuberosities and the shaft of the tibia a fracture through the neck of the fibula may also be present

As recorded previously ligamentous lesions are invariably associated with severe fractures produced by violent abduction mechanisms and to a lesser degree in fractures produced by a predominant compression force. The tibial collateral ligament always is implicated in some degree and in many instances lesions of the anterior cruciate ligament and the lateral meniscus occur, the usual lesion of the anterior cruciate ligament comprises a fracture of the tibial spine Fortunately, lesions of the tibial collateral ligament are never severe because much of the acting force is expended in producing the fracture in the lateral tibial tuberosity hence, in most instances the concomitant lesions of the ligaments are amenable to conservative treatment and are rarely responsible for instability of the knee joint, provided that the quadriceps apparatus is restored to normalcy

Inasmuch as condylar fractures of the tibia are intra articular fractures, the joint invariably is distended with blood If a massive hemarthrosis exists, aspiration of the joint is an essential preliminary step in the treatment of these lesions. Also, in recent injuries varying degrees of swelling of the pericapsular tissues occurs, particularly in the region of the femoral attachment of the tibial collateral ligament.

Diagnosis. In the majority of the cases there is a history of some form of severe injury followed by pain, complete disability and swelling of the knee joint Both active and passive motion elicits pain In the event that the lateral condyle is depressed, valgus deformity of the knee joint is discernible however the deformity may be hidden by generalized swelling of the soft tissues around the knee joint Wide separation of one or both condyles produces broadening of the tibial condylar region however, this feature may be masked by the swelling If a subcondylar fracture is present and the lower fragment is displaced upward, some shortening of the lower leg is discernible With depression and separation of the tibial condyles varying degrees of abnormal mobility may be demonstrated by abduction or adduction of the leg, depending on the condyle involved On palpation tenderness is most marked over the line of fracture if one condyle is implicated this maneuver is helpful in localizing the site of fracture in fractures involving the entire circumfer



Fig 303 Fracture of the lateral tibial condyle with minimal displacement and a relatively intact tibial plateau except in the region of the tibial spine. The subsequent degenerative alterations in this type are usually minimal in degree



Fig. 304 Severe comminutions of the lateral tibial plateau Several fragments of the articular surface are driven into the cancellous bone of the tibia. The outlook in this type of fracture is poor severe degenerative alterations invariably occur

ence of the tibial shaft immediately below the expanded upper end of the tibia tenderness is demonstrable around the entire bone In widely separated condyles without impaction lateral compression may reveal motion between the two condylar fragments they may be moved separately forward and backward Swelling and localized tenderness over the upper end of the fibula should make one suspicious of a fracture in this region

In some instances the diagnosis is difficult because there may be little or no displacement of the fragments However if blood is aspirated from the joint a fracture should be suspected Roentgenographic studies with the leg in various positions establishes the true nature of the lesion

Management of Fractures of the Lateral Tibial Condyle

General Considerations. Comprehension of the mechanisms of fractures of the upper end of the tibia is essential in order to formulate an adequate plan of treatment and to be able to prognosticate with some

accuracy the long term results In lesions with depression of the entire lateral condyle and with minimal separation, the articular surface is usually intact except at the site of fracture in the region of the tibial spine As noted previously, damage to the tibial collateral and the cruciate ligaments in these cases is not severe (Fig 303) In general, the aims to achieve in this type of lesion are restoration of the displaced condyle to its anatomic position, protection of the fracture until osseous healing is complete, and development and maintenance of quadriceps power to maximum efficiency With such a regimen, degenerative alterations rarely develop to the extent that they constitute a threat to normal performance of the joint in fact in most instances the ensuing degenerative changes are minimal in degree

The outlook is less favorable, and the management is more difficult in lesions with comminution of the lateral condyle The downward and inward force of the lateral femoral condyle not only disrupts the articular surface of the tibial condyle and splits off a large marginal segment but it drives the fragments deep into the cancellous bone of the tibia (Fig 304) Many of these fragments are completely severed of all blood supply, hence, avascular necrosis is inevitable which in turn is followed by degeneration of the overlying cartilage. In addition, the displaced fragments may be wedged between the central and the marginal fragments, obstructing satisfactory reduction Lesions of the tibial collateral and the cruciate ligaments are more severe than those associated with depressed fractures of the tibial condyle The aims of management in this severe lesion are similar in every feature to those noted for depressed frac



Fig 305 Fracture of the lateral condyle on the left side and the medial condyle on the right in the same patient. Displacement is minimal and was treated by plaster fixation and early quadriceps exercises. The result was excellent.

tures however they are more difficult to achieve Moreover because of the severe comminution of the articular surface varying degrees of degenerative arthritis invariably result After healing it is of prime importance that these joints be protected from abnormal strains incident to normal function if not the degenerative alterations will be accentuated and severe dysfunction will ensue The only safeguard against such unfavorable complications is a powerful extensor apparatus Measures to prevent quadriceps atrophy must be instituted immediately after the limb is immobilized and must be continued conscientiously throughout the entire period of treatment

Fracture of Lateral or Medial Tibial Condyles Without Displacement (Fig 305) Although these lesions are characterized by minimal osseous and ligamentous damage the knee joint may be markedly distended by a large hemarthrosis Under aseptic precautions the joint is aspirated A snug fitting unpadded plaster cast is applied extending from the groin to the toes and holding the knee in full extension Quadriceps drill is begun at once on a regulated schedule 5 minutes every hour this is followed by straight leg raising exercises and next by straight leg raising exercises against elastic resistance At the end of 2 weeks a new plaster cast is applied and exercises are performed against increasing loads now the patient is permitted out of bed with the aid of crutches The second cast is retained for 2 or 3 weeks then it is removed and flexion movements of the joint are started Weight bearing is allowed at the end of 10 to 12 weeks at this time the quadriceps should be sufficiently strong to protect the joint against abnormal strains during normal function and full flexion and extension of the joint should be attained

Depressed Fracture of the Lateral Tibial Condyle. The majority of these fractures can be reduced by traction and manipulation The patient is placed on a fracture table and a general anesthetic agent is administered If the knee joint is distended with blood aspiration of the knee is the first step in the treatment Next both feet are fastened to the foot pieces and moderate mechanical traction is applied to the extended limbs A wide muslin bandage



Fig 306 This type of fracture responds readily to traction and manipulative methods.

is passed around the inner aspect of the knee joint, and steady manual lateral traction is made by an assistant The traction should be strong enough to force the knee into a varus position, the maneuver tenses the fibular collateral ligament and the lateral portion of the joint capsule, which elevates the depressed fracture to its normal anatomic position The reduction is completed by compressing, with the surgeon's hands, the tuberosities of the tibia, if this fails to attain reposition of the fragment a compression clamp may be employed to squeeze the condyles together When the latter implement is used, it should be applied and released quickly in order to prevent necrosis of the soft tissues The amount of compression made is determined by applying the clamp to the normal knee and measuring the distance between its two faces Fractures of the medial condyle are treated in a similar manner, except that traction is made in the opposite direction forcing the knee into valgus position and utilizing the tibial collateral ligament and the medial portion of the joint capsule to elevate the depressed fracture (Fig 306) Before the limb is encased in plaster, the position of the fragment is checked by roentgenograms. If the position is satisfactory while an assistant maintains lateral traction a well molded, nonpadded cast is applied from the toes to the groin

Postreduction Management Quadriceps drill is started immediately on a regulated schedule. As in undisplaced fractures, straight leg raising first aided and then unaided is the next step in the program As



Fig 307 (*Left*) Depressed comminuted fracture of the lateral tibial condyle treated by traction manipulation and compression. (*Right*) The fragments have been realigned satisfactorily

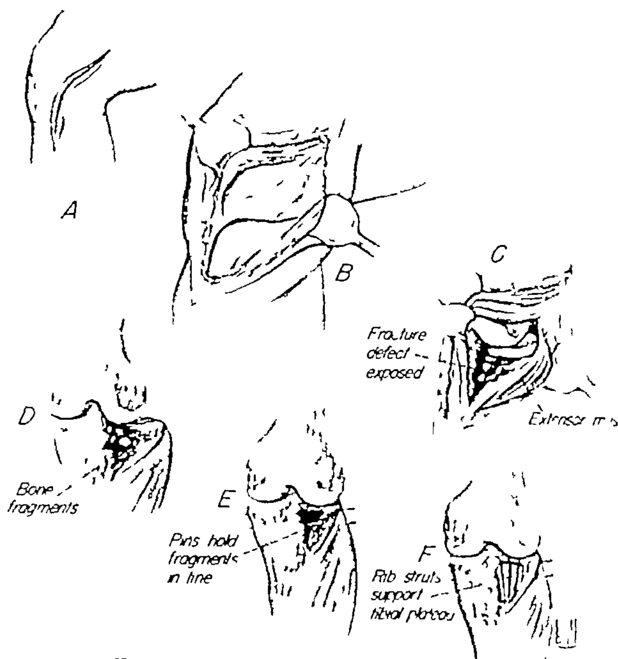


FIG 308 Replacement of fractures of the lateral tibial condyle under direct vision. Rib bone is used as struts to support the elevated articular fragments Threaded wires fix the lateral marginal fracture to the opposite tibial condyle (A) Skin incision (B) Incision in the capsule (C D) Note the lateral displacement of the marginal fragment and the comminution of the tibial plateau (F) By compression the marginal fragment is restored to its anatomic position and fixed by threaded wires (F) Rib struts are employed to support the elevated articular fragments

soon as the patient masters this step straight leg raising against elastic resistances is added this is followed by exercising the quadriceps with increasing loads After 3 weeks a new cast is applied maintaining the original position Ambulation is started on crutches but no weight bearing on the affected limb is permitted At the end of 8 weeks the cast is removed and active exercises to restore movement at the joint are started Weight bearing is allowed at the end of 10 or 12 weeks At this time the ex

tensor apparatus should be developed sufficiently so that no brace is needed for support If the quadriceps is not strong enough to provide adequate protection for the knee, the use of crutches should be continued, and the exercises should be intensified until the quadriceps has regained the desired power and volume This is far more desirable than depending upon a brace or a knee cage for stability of the knee joint.

Comminuted Fractures of the Lateral Tibial Condyle.

Closed Method Satisfactory reduction is difficult to achieve in this type of fracture. As pointed out previously, many small central fragments some of which are devoid of blood supply, may be driven into the cancellous bone of the tibia. It is impossible to restore these fragments to their normal anatomic position by traction and manipulative methods. Nevertheless, if comminution is not too severe and the marginal fragment is relatively large, by traction, manipulation and compression the latter may be elevated and compressed into a satisfactory position and the small fragments may be crushed in the head of the tibia (Fig 307) In such instances the restored articular surface of the condyle is sufficient to provide an adequate weight bearing surface Eventually the central defect in the condyle will be obliterated by fibrous tissue The technic of the reduction is similar to that described for depressed fractures of the lateral tibial condyle except that stronger lateral traction and compression are required to obtain satisfactory repositioning of the marginal fragment The postreduction management is the same as that recorded for depressed fractures

Open Method If closed methods fail to obtain a satisfactory reduction because a large marginal fragment cannot be elevated and compressed into its anatomic position and in cases with severe comminution with a small marginal fragment, operative treatment is indicated (Fig. 308) After a tourniquet is applied the skin is prepared adequately, and the lower leg is draped separately in order that the surgeon may manipulate the limb freely The skin incision is similar to that described for excision of the lateral meniscus, except that its distal end is projected downward on the head of the tibia, paralleling the outer margin of the patellar tendon. The joint capsule is opened in the line of the upper arm of the skin incision in the interval between the iliotibial band and the patellar tendon After the joint is flushed with normal saline solution to remove clots and loose fragments of cartilage and bone the lateral meniscus is excised Frequently, this latter structure is found to be lacerated and wedged between fragments displaced deeply in the head of the tibia Greater visibility of the central crater is obtained by displacing the marginal fragment outward, with a small curet, the central depressed fragments of the articular surface are elevated to their anatomic position This frequently leaves a large defect in the tibial head immediately below the elevated fragments In order to prevent redisplacement of the fragments, cortical bone struts obtained from the bone bank may be packed in the defect, they should be long enough to support the overlying fragments of the articular surface Next, the marginal fragment is elevated and compressed into its normal position Frequently, it tends to spring back when compression is released in such instances the author employs one or two threaded wire pins which pass parallel with the articular surface through the fragment and pierce the cortex of the opposite tibial condyle, the ends are cut below the level of the skin They are withdrawn at the time that the second cast is removed usually 8 weeks after operation Other surgeons employ screws or bolts to maintain the marginal fragment in the desired position The wound is closed in layers with interrupted cotton sutures While lateral traction is maintained to hold the knee in a position of varus, the limb is encased in plaster from the toes to the groin

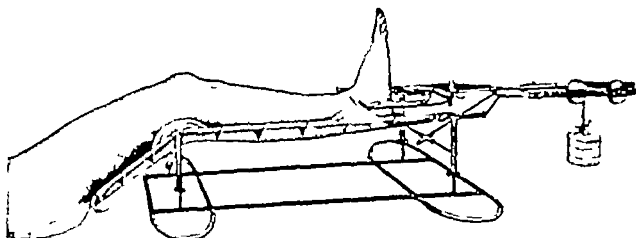


FIG 309 Method of skeletal traction employed after reduction and manipulation of T or Y fractures of the upper end of the tibia. Threaded wire is passed through the distal third of the tibia.

Postreduction treatment is similar to that described for fractures treated by the closed method

T or Y Fractures of the Upper End of the Tibia

These injuries are usually the result of violent forces acting directly downward in the line of the tibia Often the history is *one of falling from a height and landing on* the feet by this mechanism the condyles *are split and driven downward while the* shaft of the tibia is forced upward It becomes apparent that the principles of treatment comprise (1) restoration of length of the tibia by traction (2) repositioning of the condyles by manipulation and compression and (3) maintenance of the reduction until bone healing occurs Restoration of *length of the tibia and elevation of the tibial* condyles are achieved best by mechanical traction and maintenance of the reduction is assured by continuous traction which also permits early motion at the knee joint *a feature desired in these severe fractures*

Closed Methods If no contraindications prevail such as laceration of the skin or extensive soft tissue swelling treatment should be instituted at once The patient is placed on a fracture table a general anesthesia is administered and under aseptic technic the joint is aspirated After preparation of the skin a threaded pin is inserted *at a point well below the fracture site* through the lower third of the tibia the pin is attached to a spreader which in turn is fastened to the foot piece of the fracture table Mechanical traction is applied to the extended limb in the line of the tibia until *full length of the lower leg is regained The* collateral ligaments make strong upward *traction on the tibial condyles elevating* them to their normal position Any separation of the condyles is corrected by manual compression or if this is ineffective by compression made by a Scudder screw clamp or Böhler s redresseur At the termination of the reduction an elastic compression bandage is applied If roentgenograms show *acceptable repositioning of the fragments* an assistant maintains the traction while the wire spreader is freed from the foot piece While traction is still maintained the patient is transferred from the fracture table to a fracture bed and the extremity is adjusted to a Bohler Braun splint from 10 to 12 pounds of traction is applied to the leg *(Figs 309 and 310)*

Postreduction Management Quadriceps drill is started immediately but active

motion at the knee joint is not allowed for 4 or 5 weeks depending on the severity of the lesion Motion at the knee joint is performed with the traction acting, redisplacement of the fragments is inevitable if this rule is disregarded From 6 to 8 weeks after reduction, skeletal traction is discontinued, and the pin is removed Now more intensive exercises to regain joint motion and quadriceps power are instituted. Ambulation is permitted on crutches, weight bearing is not permitted for 12 to 16 weeks.

In the event that abrasions or laceration of the soft tissues preclude immediate reduction by the aforementioned method the extremity should be splinted elevated and enveloped in hot dressings Antibiotics are administered After 7 to 10 days, the soft tissue reactions usually have subsided sufficiently to allow reduction of the fracture

Open Methods. An attempt to obtain a reduction by traction and manipulation should be made in all cases of T or Y fractures If this method fails, one is forced to resort to open methods A tourniquet is applied high on the thigh, and the pin in the tibia with the attached tautener (spreader) is not disturbed The leg is draped separately so that the surgeon may manipulate it freely and, if necessary, use the pin to apply traction to the lower leg Two skin incisions are made one on each side of the knee joint they are similar to the incisions employed for excision of the menisci but in addition are continued downward on the head of the tibia parallel with the margins of the patellar tendon The joint capsule is opened between the collateral ligaments and the margins of the patellar tendon flexion of the knee joint brings into view the articulating surfaces of the tibia After all clots and free blood are flushed out of the joint the menisci are inspected and excised frequently they are found to be damaged and displaced between the fragments Removal of the fibrocartilages facilitates replacement of the depressed fragments. By traction and manipulation length of the tibia is restored



Fig 310 Fracture of both tibial condyles and the shaft of the tibia This type is treated best by traction, manipulation and compression and then placing the limb in the apparatus depicted in Figure 309

and by leverage and compression the marginal and depressed fragments are restored to their normal position As in comminuted fractures of the lateral condyle, the fragments are approximated and squeezed together with a screw clamp While traction and compression are maintained two threaded wires are passed parallel with the articular surface, starting on the lateral side and traversing the entire width of the condylar region of the tibia the points of the pin should pierce the cortex of the medial tuberosity the ends of the pins protruding from the lateral tuberosity are cut short so that they lie directly under the skin and are readily accessible. The author has found



FIG 311 Advanced degenerative alterations following comminuted fracture of the lateral tibial condyle The patient has little discomfort and is capable of full extension and flexion of the knee to 80° He possesses a powerful quadriceps which protects the joint from abnormal stresses incident to function.

threaded wires to be more serviceable than bolts and screws They should be inserted while the fragments are held together firmly If necessary one or more pins may be passed obliquely fixing the condyles to the shaft of the tibia The wounds are closed in layers While traction is maintained the patient is transferred to a fracture bed and the limb is placed on a Böhler Braun splint from 10 to 12 pounds of traction is applied to the pin The postoperative management is similar in every feature to that described for T or Y fractures treated by closed methods

ARTHRODESIS AND ARTHROPLASTY OF THE KNEE JOINT

Not infrequently, pronounced degenerative changes develop following severe disruption of the osseous and the cartilaginous elements of the knee joint In some instances because of failure to achieve normal alignment of the fragments or because of other circumstances that precluded early and satisfactory reduction of the fracture the affected knee joints exhibit varying degrees of deformities in the frontal or the sagittal planes as well as instability and restricted and painful motion In cases with minimal or no deformity of the knee joint with advanced degenerative alterations much can be done to improve function and alleviate pain by improving the power and the stabilizing effect of the quadriceps apparatus and by removal of factors responsible for internal derangement of the knee joint, such as damaged menisci and loose bodies (Fig 311) On the other hand the extent of damage may be irreparable and more radical measures must be employed to rehabilitate the patient A knee joint with only a few degrees of painful motion is a serious handicap particularly in individuals whose occupations demand long hours of standing and walking The indications and the contraindications for arthrodesis and arthroplasty are discussed in Chapter 13 "Surgical Approaches and Procedures" however at this time it must be pointed out that the decision in a large measure is governed by the sex the age and the occupation of the patient In addition the determination of the patient to regain motion after an arthroplasty is performed must be given prime consideration A well-executed surgical procedure that is mechanically sound is no assurance that a good functioning joint will be the end result In patients whose work demands long hours of weight bearing an ankylosed knee joint provides a stable useful limb capable of meeting all

strenuous functional demands The technics of arthroplasties and arthrodeses are de scribed in Chapter 13, Surgical Approaches and Procedures'

FRACTURES OF THE UPPER END OF THE FIBULA

Isolated Fractures

These fractures are produced by direct violence to the outer surface of the knee joint. The fracture line may traverse the head or the neck of the fibula in an oblique or transverse plane, as a rule, there is rela tively little displacement of the fragments The diagnosis is readily established by (1) a history of direct violence to the outer aspect of the knee, (2) localized swelling and tenderness in the region of the head and the neck of the fibula, (3) compression of the tibia and the fibula in the middle of the leg projects pain at the site of fracture and (4) rotation of the foot while the knee is flexed also elicits pain in the involved area of the fibula Roentgenographic study con firms the diagnosis

Treatment. Because there is minimal or no displacement of the fracture, reduction is not necessary In most instances after the pain of the initial injury has subsided, the patients experience little discomfort except on weight bearing Such cases need no ex ternal fixation they should be made ambu latory with the aid of crutches. At the end of 3 to 4 weeks weight bearing is permitted and the crutches are discarded Some pa tients have considerable pain this is due to the action of the biceps femoris muscle, which inserts in the upper end of the fibula and tends to distract the fragments, particu larly on active flexion of the knee joint. In these individuals a snug fitting plaster cast is applied from the toes to the groin, hold ing the knee slightly flexed After 4 weeks the cast is removed but no weight-bearing is permitted on the affected limb for 2 more weeks however the patient is able to get about on crutches.

Fractures in the region of the neck of the fibula or its upper third may be complicated by injury to the peroneal nerve it may be contused or crushed at the time of the in jury or it may be incorporated in a mass of callus In the latter instances, symptoms pointing to implication of the peroneal nerve are manifest slowly several weeks after injury, in the former, paralysis is im mediate Treatment comprises putting the anterior tibial, the peroneal and the extensor muscles of the foot at rest by supporting the foot in a position of dorsiflexion After healing of the bone is complete, a short leg brace supporting the foot in the desired po- sition should be applied In the event that no clinical evidence of return of power is evident in the aforementioned muscles with in 2 to 3 months, exploration of the nerve is indicated If it is severed its ends are ap- proximated, if it is caught in callus, it is freed The method of exposure of the nerve is recorded in Chapter 13 Surgical Ap- proaches and Procedures "

In rare instances the proximal fragment of the fibula is displaced upward and back ward by the biceps femoris muscle Flexion of the knee may fail to approximate the fragments In such cases open reduction and fixation of the fragment to its normal posi tion with sutures is indicated After opera tion a plaster cast is applied from the toes to the groin, holding the knee in at least 45° flexion The cast is removed at the end of 4 weeks and weight bearing without crutches is permitted after 2 more weeks have elapsed

Forceful adduction of the knee may pro- duce an avulsion of the fibular collateral ligament with a portion of the styloid proc ess of the fibula. This lesion may be accom panied by stretching of the peroneal nerve and rupture of the lateral portion of the capsule of the joint. The treatment is dis- cussed in Chapter 8, "Traumatic Lesions of the Ligaments " Usually, surgical interven tion is required to restore the avulsed frag



FIG 311 Advanced degenerative alterations following comminuted fracture of the lateral tibial condyle. The patient has little discomfort and is capable of full extension and flexion of the knee to 80 He possesses a powerful quadriceps which protects the joint from abnormal stresses incident to function

threaded wires to be more serviceable than bolts and screws They should be inserted while the fragments are held together firmly If necessary one or more pins may be passed obliquely fixing the condyles to the shaft of the tibia The wounds are closed in layers While traction is maintained the patient is transferred to a fracture bed and the limb is placed on a Böhler Braun splint from 10 to 12 pounds of traction is applied to the pin The postoperative management is similar in every feature to that described for T or Y fractures treated by closed methods.

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ment of bone with the attached ligament to its normal position

Dislocation

This rare lesion may be the result of direct violence, driving the head of the fibula upward backward or outward or it may be due to indirect violence as the result of a fracture of the tibia at a lower level, in which case the head of the fibula may be levered from its attachments and displaced upward in addition to one of the above positions The diagnosis is not difficult to establish. Inspection and palpation detect the abnormal position of the bone roentgenograms taken in different views confirm the diagnosis

Management. Reduction is usually achieved by manipulation of the fragment combined with inversion of the foot If the bone tends to spring out of its normal position it should be strapped firmly in place with adhesive and the leg should be encased in plaster from the toes to the groin with the knee flexed Care should be taken to avoid injuring the peroneal nerve by the adhesive strapping The cast is removed at the end of from 4 to 6 weeks and weight bearing is permitted If redisplacement of the bone occurs in spite of this method then surgical intervention is justified Under vision the bone is replaced in its anatomic position and sutured to the surrounding tissues In one case a threaded wire was passed through the fibula and the tibia crossing the proximal tibiofibular joint the wire was cut below the level of the skin it was removed 4 weeks later

WOUNDS OF THE KNEE JOINT

Penetrating wounds of the knee joint sustained in civil life or on the battlefield must be listed among the most serious injuries that may be inflicted on an individual The immediate disruption of the components of the joint and the soft tissues as well as the osseous and the cartilaginous elements may be prejudicial to restoration of normal function, in addition the wounds may introduce into the joint pyogenic organisms which may overcome the natural barriers of the local tissues and initiate a suppurative process which if managed inadequately may cost the patient his limb or life The literature abounds with material on the management of these injuries It is interesting to note the divergencies in opinion relative to what is considered to be correct treatment Some surgeons attack the problems with a sense of defeatism and resort to extreme radicalism, while others pursue a more conservative course and are bolstered by optimism in the knowledge that if certain surgical principles are respected the patient s own resistance and natural defenses will band together to abort a potential pyogenic process or if present eradicate the process During World War I the French were of the opinion that an established pyoarthrosis invariably resulted in loss of limb or threatened life This belief was responsible for the radical measures instituted In severely damaged joints primary resection was advocated as a prophylactic measure and if sepsis in a knee joint could not be controlled promptly by adequate drainage and immobilization secondary resection was performed These methods were carried over into World War II the Germans and the Russians also advocated early resection in order to prevent sepsis of the knee joint In 1941 Ogilvie recorded that if sepsis of the joint was not controlled within 4 days deletion of the limb was usually required to save the patient s life

It is paradoxical that wars in which limbs and lives are sacrificed needlessly by the thousands must provide the material which permits surgeons to formulate means and methods to save limbs and lives. Even at this enormous price many lessons learned under the most trying circumstances are soon forgotten and must be relearned in the next struggle

During a 22 month tour of duty in the

Pacific area, the author treated hundreds of fresh casualties, many of which received severe injuries of the knee joints. Some of these were brought aboard within a few hours after the injury was sustained, these soldiers had received no treatment other than the first aid measures given by a corps man This usually comprised sprinkling the wound with sulfonamide powder applica tion of a compression bandage and adminis-tration of morphine Other casualties were first seen several days after they had re ceived their wounds As a rule, these had no definitive treatment because of the con ditions under which the medical personnel on the beaches and in small crafts were working Most of the casualties were kept aboard several weeks after the definitive surgery was performed so that it was pos-sible to evaluate the methods of treatment employed of course, this evaluation ap-plied only to the problem of sepsis At this time (1943 to 1945) the observations and the recommendations in the management of penetrating wounds and sepsis of the knee joint recorded by Hampton were not known however, the observations of the author parallel those noted by Hampton, and their adoption is recommended

Treatment of Penetrating Wounds

NATURAL RESISTANCE OF THE JOINTS

Now it is generally accepted that articu lar cartilage and the synovial membrane are endowed with appreciable powers of resist ance against pyogenic organisms in fact this immunity to infection surpasses that possessed by tendons bones and extra articular tissues The articular cartilage is capable of resisting the deleterious effects of proteolytic enzymes and pyogenic organ isms for long periods of time before it is severely damaged this is especially true of the calcified stratum of the hyaline carti lage.

Many observers have noted the bacterio-static or bactericidal peculiarity of the syn ovial fluid Pool, during World War I, was of the opinion that the poor results ob-tained in wounds of the knee joints were due in part to the failure of surgeons to understand the powers of resistance to in fection possessed by the synovial fluid This observer recorded that closure of the syno-vial membrane after complete toilet of the joint cavity had been accomplished was in dicated in wounds sustained for as long as 24 hours After all injuries to the knee joint, copious amounts of synovial fluid are poured into the joint cavity this is a natural reac tion of the synovial membrane in response to noxious irritants Hence, the synovial fluid that essentially comprises plasma be comes a natural vehicle for the conveyance of antibodies, macrophages and medicinal agents such as sulfa drugs and antibiotic agents

GENERAL MEASURES

Penetrating wounds of the knee joint are often associated with profound shock and hemorrhage It becomes apparent that be-fore definitive local treatment is adminis-tered, the patient s general condition must be improved This is accomplished by ad ministration of morphine to relieve pain application of external heat, and transfu sions of blood or plasma, hemorrhage is controlled by compression bandages Dur ing this interval the affected limb is splinted a sterile dressing is placed over the wound, and ice packs are placed around the knee and the lower limb In addition, the patient is given an adequate dose of tetanus anti toxin and polyvalent gas gangrene anti toxin. When the patient s general condition is improved, roentgenographic studies are made of the affected region, roentgeno-grams should be taken from different angles in order to localize any metallic bodies that might be present

Preparation of Skin and Wound A tourniquet is used to obtain a dry field. The wound is exposed by cutting away all ar ticles of clothing and dressings Thorough

cleansing of a wide area of skin up to the wound edges is the first step in the toilet of the wound The wound is covered with sterile gauze and the skin is cleansed meticulously with tincture of green soap then the soap is washed off with normal saline solution The wound itself is now cleansed with tincture of green soap, using cotton balls so as not to traumatize the raw edges of the wound, this scrubbing procedure is carried out under a constant stream of saline solution that flushes out the wound continuously Several gallons of solution may be used in the cleansing process, depending upon the severity of the lesion Strong antiseptic solutions are not necessary and may be harmful by causing further irritation of the tissues that already have sustained severe damage

Excision of Soft Tissue *It is erroneous* to excise the skin edges widely usually excision of a strip of skin measuring ⅛ to ¼ inch is sufficient After the skin edges are reflected all devitalized subcutaneous tissue fascia and muscle must be removed It may be necessary to enlarge the skin wound in order to obtain adequate exposure of the underlying tissues In carrying out this step of the débridement the tissues at all times must be handled with gentleness strong traction to expose deep tissues *must be condemned* The surgeon should work dexterously and thoroughly from the superficial to the deep layers With sharp scissors *all* shreds of fascia and portions of devitalized and lacerated muscle are cut away Segments of muscles which no longer contract when stimulated mechanically or fail to bleed when incised should be removed The defect in the synovial membrane is inspected and all tags and shreds are excised At this point the entire wound *is flushed* again with normal saline and the edges of the soft tissue wounds are protected with warm gauze packs and the interior of the wound is inspected

Intra-articular Débridement. Occasionally little wounds of entry are too small to *permit adequate toilet of the intra articular* structures In these cases, after the wound is débrided as described above a separate standard incision usually one of the parapatellar incisions is employed to expose the joint All loose foreign material, unattached fragments of bone and cartilage and all fragmented articular cartilage are removed If the menisci are lacerated or show other evidence of injury they are excised Foreign material buried in the cancellous bone of the femoral condyles or the tibial tuberosities is removed, and the margins of the defect are made smooth. Severe comminution of the patella is not an infrequent concomitant lesion In these cases all the patellar fragments should be excised However if only one of the poles is shattered the bone fragments are removed and the main *fragment is left behind, however, its raw* surface is trimmed evenly Débridement of the joint is completed by irrigating the joint cavity with copious solutions of normal saline

Damage to the articular surface may be so extensive that any restoration of function in the knee joint is impossible In such cases the remaining articular cartilage is removed It may be necessary to resect the ends of the bones in order to attain good *approximation of the bone ends* the wound is now treated as a compound fracture

Closure of the Synovial Membrane Many controversial views have been recorded relative to the wisdom of closure of the synovial membrane following débridement of penetrating wounds of the knee joint However clinical experience reveals that the relatively high immunity of the intra-articular structures to infection is justification for primary closure of the synovial *membrane In addition* the experience of many workers indicates that exposed joints even when chemotherapy and antibiotic agents are employed *invariably* are invaded by secondary pyogenic organisms and that the unprotected hyaline cartilage degenerates rapidly It becomes *apparent that every*

effort must be made to suture the synovial membrane In the event that closure is im possible because of the loss of soft tissue, flaps of fascia or skin may be rotated to effect the closure Also, continuous drainage is not justified in knee joints with evidence of frank infection, except in those cases that exhibit such extensive destruction that any useful restoration of function is impossible to achieve.

Time Interval. Some surgeons are of the opinion that wounds adequately treated by débridement and lavage within 6 to 8 hours after injury may be closed by primary su ture After 6 or 8 hours but under 24 the capsule may be closed, but the extra articu lar tissues should be left open until all dangers of infection have passed after 24 hours débridement of the wound should not be performed rather contaminated tissues should be incised freely, and the wound left wide open Drainage is secured by packing the joint with gauze This is not in agree ment with the experience of other surgeons, including the author who is in agreement with the observations and the recommenda tions made by Hampton This observer noted that the time interval between sustaining the injury and the initial operation should not determine the type or the radi calism of the surgical procedure His expe rience reveals that the preferred plan of treatment in all cases comprises adequate exposure of the joint excision of all devital ized soft tissue, removal of cartilaginous and bony debris copious lavage of the joint cavity closure of the synovial membrane and capsule and immobilization of the limb in a plaster hip spica or Tobruk splint This plan of management is also recommended for cases of potential or established suppurative arthritis

Closure of Extra-articular Cellular Tissues. These tissues are more likely to become infected than the knee joint how ever if a period of not more than 6 or 8 hours has elapsed since the time of wound ing, the author does not hesitate after thor ough débridement to do a primary closure of all layers. If the soft tissue damage is severe, a small drain may be inserted be neath the subcutaneous layer, the drain is removed at the end of 12 to 24 hours If more than 6 or 8 hours have elapsed from the time the wound is sustained, these tissues should not be closed at the time of the initial operation After débridement and closure of the synovial membrane and capsule, the soft tissue wounds are left open, a light gauze packing impregnated with petrolatum is inserted between the wound edges After 5 to 7 days, secondary closure of the wound is performed, using as little absorbable suture material in the depths of the wound as possible Through and through sutures of steel wire are preferred

Chemotherapy Chemotherapy and anti biotic agents are responsible in a large measure for the excellent results attained in penetrating wounds of joints, particularly the knee joint. However their use is no sub stitute for thorough and meticulous débridement, which is the most pertinent feature in the management of these lesions After closure of the synovial membrane and per haps the capsule, penicillin (50,000 to 100,000 units) is instilled directly into the joint cavity Also, penicillin therapy is ad ministered systemically, 100,000 units every 6 hours. Sulfa drugs may be given also sulfadiazine is tolerated best Aspiration of the joint and instillation of penicillin may be performed daily or every second day, de pending upon the severity of the wound and the type of case, when performing this procedure the arthrotomy site should not be exposed or disturbed In contaminated wounds frequent aspiration and instillation of penicillin may not be necessary, how ever in infected cases local instillation of the antibiotic at frequent intervals is man datory until the local systemic reactions of the patient indicate that the infection is under control

Immobilizaton and Mobilization of the Limb It is now generally accepted that

complete immobilization and elevation of the affected limb are essential in promoting tissue healing and enhancing the power of the local tissues to combat and overcome infection During World War I Willems *advocated forced active motion and drainage* of the knee joint This treatment has fallen into disrepute It violates all basic principles of sound surgery—clinical experience has confirmed this It enhances toxic absorption from the infected area and promotes spreading of the infection in the extra articular cellular tissues and along the fascial planes of the extremity After débridement is complete, the synovial membrane closed, and the joint cavity filled with penicillin solution a plaster spica should be applied, extending from the costal cage to the toes of the affected limb A window is cut over the knee joint to permit aspiration of the joint and inspection of this region The limb should be elevated, and meddlesome handling such as repeated dressings should be avoided In cases with no evidence of infection active contraction of the quadriceps muscle is instituted as soon as the local tissue reactions have subsided after 2 to 3 weeks, depending on the extent of the soft tissue damage the cast is removed and the limb is placed in balanced suspension using a Thomas splint with a Pearson attachment all movements in the joint are started from the position of full extension this prevents the development of flexion contractures In infected cases quadriceps drill is commenced when control of the infection is achieved as a rule the patient is ready to be taken out of plaster and transferred to the balanced suspension apparatus at the end of 2 to 4 weeks In cases with little or no bony or cartilaginous involvement ambulation on crutches is permitted at the end of 4 to 8 weeks Unprotected weight bearing is usually possible after 10 to 12 weeks. Cases with extensive bony involvement present more difficult problems The time to allow weight bearing in these cases is governed by the severity of the articular damage and the presence or the absence of intra articular fractures implicating the condyles of the femur and the tibia. Nevertheless active nonweight bearing exercises should be performed diligently to restore maximum quadriceps power and flexion and extension movements of the joint During the period of rehabilitation there is a persistent tendency of the knee to develop flexion contractures. This can be overcome best by active extension exercises and the use of night splints made of plaster Braces or cages should not be used except as a last resort Night splints are worn until all symptoms subside and the extensor mechanism has developed sufficient power to preclude flexion contractures It is important to emphasize that at all times exercises must be performed within the patient's tolerance overenthusiasm on the part of the surgeon or the patient may result in soft tissue reactions synovitis or hemarthrosis On the other hand the program should be so arranged that there is a steady progression in the intensity of the exercises.

Classification of Penetrating Wounds of the Knee Joint

Penetrating wounds of the knee joint can be grouped into three categories.

Group 1 comprises penetrating wounds with minimal soft tissue damage with no implication of the cartilaginous or the bony elements of the articulation Such a lesion may be produced by a high velocity bullet falling on a piece of glass or a nail foreign material is not deposited in the joint or the extra articular tissues The management of this type of lesion is relatively simple it comprises trimming of the wound edges lavage and closure of the wound The joint is aspirated and from 50 000 to 100 000 units of penicillin are instilled into the joint A plaster spica is applied from the costal cage to the toes of the affected limb also systemic antibiotic therapy and one of the sulfa drugs are administered The aspirated material should be examined for pyogenic

organisms. Repeated aspiration (every 24 or 48 hours) may be necessary to keep distention of the joint at a minimum, at each aspiration penicillin is instilled locally After the acute reactions, both local and systemic, have subsided, quadriceps drill is instituted At the end of 2 or 3 weeks the cast is removed, and the limb is placed in balanced suspension (Thomas splint with a Pearson attachment), now active flexion and extension exercises are started, the exercises must be executed on a regulated program. When the limb is at rest in the suspension apparatus, it lies in the extended position, all flexion exercises begin from this position.

Group 2. In this group the extent of the soft tissue damage is more extensive than in Group 1 but only minimal or moderate damage of the bony and cartilaginous components of the joint is present The damage may involve the condyles of the femur or the tibia or comprise a fracture of the patella. Foreign material such as bullets, pieces of shrapnel or a splinter of wood, may be lodged in the bone This group demands excision of the wound edges and thorough intra articular exploration and débridement After the wound edges are excised and all devitalized soft tissue is trimmed away, all instruments are changed and the surgeon and the assistants put on fresh sterile gowns and gloves Foreign material previously localized by roentgenographic study must be found and removed (Fig 312) Devitalized intra-articular soft tissues cartilage and bony fragments must be removed Although it is desirable to remove all metallic bodies buried in the condyles of the femur and the tibia some may lie deep in the substance of the bone at a distance from the articular surface or joint cavity (Fig 313) Exposure and removal of these bodies would increase the extent of the surgical trauma and necessitate exposure of large areas of cancellous bone in which the powers of resistance to infection is relatively low In such instances, it is better surgical judgment not to disturb the metallic fragments Finally, the wound is flushed thoroughly with normal saline solution and the synovial membrane and the capsule are closed, and penicillin is injected into the joint cavity In the event that loss of soft tissue is extensive and closure of the synovial membrane or the capsule is not possible closure of the joint cavity should be effected by rotating a piece of fascia or skin to close the defect If the interval between wounding and operation does not exceed 6 or 8 hours the skin is closed loosely, if the



Fig 312 Pieces of shrapnel in the knee joint. Intra-articular damage to the bone and the articular cartilage is minimal. Regardless of the time interval the foreign bodies should be removed, the joint cavity flushed, and the synovial membrane sutured (Dr Wiggins)

interval is longer, the superficial layers of the wound are packed lightly with petrolatum gauze secondary closure is done from 5 to 7 days later The postoperative management is described in the preceding section

In this group the immediate results in terms of joint function are governed by the extent of the damage to the cartilaginous and bony elements of the joint and the degree to which the mechanics of the joint have been altered In general lesions of the tibial plateaus result in less dysfunction than lesions of the femoral condyles Varying degrees of degenerative arthritis develop in all cases the amount of long term disability depends upon the location and the severity of the articular damage the extent of the alterations in the normal mechanics of the joint and the functional demands made on the joint by the patient

Group 3 In this group all components of the joint are severely disrupted including bone, cartilage muscles and skin The severity of the wounds renders these limbs readily vulnerable to infection If there is a remote possibility of restoring some useful function the lesions are treated along the lines described in *Group 2* If the damage is irreparable the remaining articular cartilage may be removed, or the ends of the bone may be resected inducing a primary arthrodesis of the joint If an attempt is made to salvage some motion the synovial membrane or the capsule is closed If in these cases loss of soft tissue precludes closure a flap of soft tissue is shifted into the defect to effect closure of the joint cavity The periarticular tissues are sutured at the end of 5 or 7 days When the destruction of tissue is so severe that any return of useful function is impossible and the soft tissues cannot be approximated the wounds are packed with petrolatum gauze the



Fig 313 Obviously, it is impossible to remove all the metallic particles in this case The joint should be explored and débrided and all accessible particles should be removed The synovial membrane should be closed (Dr Wiggins)

packing extends to, but not into, the joint. As noted previously, these lesions are especially vulnerable to infection hence, débridement must be thorough, and all foreign materials must be removed Failure to achieve this results in infection and the formation of sinuses Chemotherapy and immobilization of these lesions are the same as indicated in Group 2 In the event that bony ankylosis of the joint is desired, plaster fixation is continued until it is achieved

Occasionally, the lesions are associated with irreparable damage to the large vessels of the leg If gangrene of the limb is inevitable amputation must be performed

Infected Knee Joint

As recorded previously, the author is in agreement with the work of Hampton relative to the management of the infected knee joint The success of this method of management is based on thorough removal of all devitalized soft tissues cartilage and bone and foreign material inside or in close proximity to the joint cavity, in addition, local instillation and systemic administration of penicillin plays a major role in overcoming the existing infections The technic of the treatment is similar in every feature to that described for cases in Group 2, this method is employed regardless of the time interval between wounding and operation Closure of the synovial cavity is essential if the degree of joint destruction is not too severe and if some joint motion is anticipated If the severity of the damage to the joint components precludes any useful function, the joint cavity is not closed In these cases continued drainage and sepsis may be prevented by resection of the bone ends and excision of a comminuted patella Although this is radical surgical treatment, the method enhances early healing and ankylosis of the joint with the limb in the position of function. The amount of bone resected is governed by the extent of the bone destroyed as much as 2 to 2½ inches of shortening may be accepted In chronic sepsis of the knee joint resection is more desirable than amputation, if shortening of the limb is not extreme

The principles of the treatment of wounds of the knee joint described herein have been crystallized from experiences in the management of war wounds They are also applicable to wounds sustained in civilian practice. In the latter cases the immediate and long term results should be better than those in the former In civilian practice, as a rule the wounds are less severe Intra-articular damage rarely assumes the proportions observed in war wounds contaminated foreign bodies are rarely deposited in the joint cavity or in the osseous elements of the joint and initial treatment is administered early and under more favorable conditions

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10

Loose Bodies

The etiology and the pathogenesis of loose bodies of intrinsic origin encountered in the joints have been subjects of much speculation and controversy. Ambroise Paré is credited with the removal of the first loose body from a joint. In 1558 he successfully removed a "stone" from the knee joint. Since this incident keen interest in loose bodies has been manifested by numerous investigators, both on the continent and in this country. Particular attention has been focused on the entities now identified as osteochondritis dissecans and synovial osteochondromatosis. For practical purposes loose bodies in joints arise from (1) the articular surfaces of the ends of the bones (in the case of the knee joint they arise from the articular surfaces of the femoral condyles, the tibia and the patella), (2) from pathologic tissues incident to degenerative arthritis (in this group trauma may be a factor in detaching the body from its site of origin) and (3) from the synovial membrane. However, for the sake of completeness the classification of Mercer is recorded herein; this is a modification of the classification of Fisher.

CLASSIFICATION OF LOOSE BODIES (MERCER)

A. Fibrinous loose bodies (structureless bodies composed of fibrinous material or of necrotic synovial membrane)
   Traumatic
      After hemorrhage
   Pathologic, in association with
      1. Tuberculosis
      2. Chronic synovitis

B. Fibrous loose bodies (composed of fibrous tissue)
   Traumatic
      Organization of hemorrhage into villus
   Pathologic, in association with
      1. Tuberculosis (nodular tuberculosis)
      2. Syphilis (gummata)
      3. Osteoarthritis

C. Cartilaginous loose bodies (composed entirely of cartilage cells)
   Traumatic (separation of whole or part of an intra-articular fibrocartilage, e.g. meniscus)

D. Osteocartilaginous loose bodies
   Traumatic
      Displacement of nonarticulating epiphysis
   Pathologic
      1. Detachment of portion of articular surface (osteochondritis dissecans)
      2. Detachment of osteophytes (in tabes dorsalis and osteo-arthritis)
      3. Separation of sequestra (in tuberculosis and acute arthritis)
      4. Synovial chondromata

E. Miscellaneous loose bodies
      1. Introduced foreign bodies
      2. Lipoma
      3. Angioma
      4. Secondary carcinoma, etc.

Of the numerous types of loose bodies enumerated in the aforementioned classification, only those which are encountered most frequently are discussed in this section. The etiology and the pathogenesis of some of the other types are apparent and do not require consideration in detail.

OSTEOCHONDRITIS DISSECANS

This designation is applied to loose bodies in joints arising from the articular surfaces of the ends of the bones. The detachment of the bodies from the host bone occurs slowly over a period of months or even years This entity differs from that in which loose bodies are the result of violent injury, displacing immediately a fragment of articular cartilage or articular cartilage and subchondral bone into the joint cavity an example of this latter lesion would be subosteochondral fracture of the patella

The term was conceived by Koenig in 1887 This is the most frequent entity associated with loose bodies The knee is involved most often, in the author s series the condition was found in 92 per cent of the cases of loose bodies from all causes In most instances one loose body is observed rarely more than 2 or 3 are encountered In the knee the common site of origin is in the lateral aspect of the medial condyle of the femur, occasionally from the articular surface of the patella and in cases of recurrent dislocations of the patella, the body may arise from the lateral aspect of the lateral condyle of the femur Next in order of frequency the lesion is observed in the elbow joint, usually implicating the capitellum also it may occur in the hip, the shoulder and the ankle Generally, one joint is involved occasionally the lesion is observed in both knees (Fig 314)

Etiology and Pathogenesis

Although some workers believe that trauma in some form is the most plausible causative factor responsible for osteochondritis dissecans sufficient clinical data is available to discredit this premise Some of the prevailing theories advanced by different investigators are recorded herein Essentially the numerous theories propounded attempt to provide an explanation for the separation of a fragment comprising articular cartilage or articular cartilage and subchondral bone, from the articular ends of the bones At all times the traumatic theory has had many supporters

The traumatic concept received its greatest impetus when Monro (1726) first observed that a loose body found in the knee joint had a corresponding defect in the medial condyle of the femur A history of severe injury to the affected knee, in some of the cases, lends support to this theory However, in the absence of a history of sudden violence or even appreciable minor trauma, some other explanation must be provided in defense of the traumatic theory of origin In 1854 Broca recorded the belief that repeated minor traumata were responsible for impairment of circulation of the affected area, this was followed by necrosis, gradual loosening and eventually sequestration of the area The frequent absence of a history of trauma in many cases of loose bodies stimulated Koenig to seek another explanation In 1888 he recorded his views, he was of the opinion that some unknown agent initiated a process of necrosis which in turn caused occlusion of the vascular bed of the affected area with subsequent separation of the area This pathologic process was a "dissecting osteochondritis" which resulted in separation of the fragment Before separation occurred fibrous tissue invaded the interval between the fragment and the end of the bone so that both raw surfaces were covered by a layer of fibrous connective tissue Koenig believed that in some instances the loose bodies were detached by severe trauma however, in the greater majority of the cases they were detached by the aforementioned pathologic process

Some observers are of the opinion that trauma in the form of impaction of the adjacent articulating surfaces such as is produced in movements combining flexion and rotation may result in shearing a fragment of bone from one of the articular surfaces The fragment may be displaced immediately into the joint cavity or it may

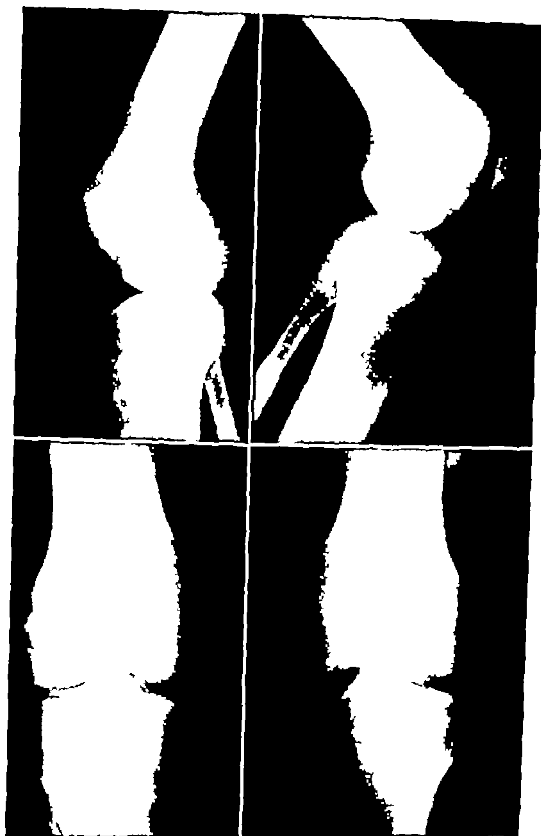


Fig 314 *Osteochrondritis dissecans of both medial femoral condyles of the* same individual aged 18 The defects in both condyles were sharply circumscribed at operation. On the left side 3 bodies were found 1 was free in the joint and the *remaining 2 were attached loosely to their bed in the femoral* condyle On the right 1 body was found it was attached loosely in its niche The medial meniscus revealed a longitudinal tear

remain partly attached in its bed subsequent minor traumas complete the separation. Kappis was an ardent supporter of this theory He was of the opinion that loose bodies observed in the articular surface of the patella are the result of tangential forces Furthermore he pointed out that in cases lacking violent injury a predisposition caused by disease or congenital disturbance of the affected cartilage must exist This provides an explanation for instances of bilateral joint involvement

Barth on the other hand believed that the pull of intra articular ligaments detached fragments of bone at their sites of insertion He recorded that more loose bodies were produced by the pull of ligaments than by impingement of adjacent articular surfaces This mechanism fails to explain the cause of separation of areas in which no ligaments are attached

Another interesting mechanism of impingement of adjacent surfaces was recorded by Freiberg This observer noted that in many cases the tubercles of the tibial spine are unusually prominent, particularly the medial tubercle He believed that flexion of the knee and external rotation of the tibia caused impingement of the tubercle on the medial condyle in the region of the insertion of the posterior cruciate ligament He speculated that this impingement may damage terminal blood vessels in this situation and result in impairment of circulation to the area in the end of the bone supplied by the terminal vessels Roesner believed the lesion was the result of direct impingement of the intercondyloid eminence of the tibia against the lateral aspect of the medial femoral condyle Smillie also supports the traumatic theory believing that abnormally prominent tibial spines impinge against the medial condyle of the femur the lesion may be the result of a single or repeated impingement He points out that this mechanism is enhanced by laxity of the supporting structures of the knee joint particularly when the anterior cruciate and the tibial collateral ligaments are stretched or torn When the loose body arises from the center of the articular cartilage of the lateral or the medial femoral condyle he maintains the view that the lesion is produced by repeated impingement of the affected area against either the anterior extremity of a longitudinal tear of the meniscus or against a pedunculated tab of the meniscus based anteriorly To explain separation of large portions of the articular surface in areas which could not be affected by the aforementioned modes of trauma this observer believes that in violent rotary injuries the femoral condyle is impacted against the articular surface of the tibia and the meniscus, twisting a segment of cartilage and subchondral bone out of the articular surface of the femur

Axhausen (1914) also was of the opinion that trauma played a major role in the development of the lesion According to this worker impaction of the opposing articular surfaces resulted in damage to the blood vessels to the area partial intra articular fracture may or may not occur this was governed entirely by the intensity of the violence Impairment of the circulation leads to necrosis of the area this is followed by a zone of absorption which causes gradual separation and essential displacement of the fragment into the joint He maintained that in both partially or completely detached fragments the bony elements exhibited total necrosis while the cartilage components disclosed only partial necrosis He assumed that trauma was the prime causative agent in the knee joint he observed that during motion the patella rides continuously over the area where osteochondritis dissecans is more apt to develop Later in his work he believed that trauma laid the basis for occlusions of end arteries by bacterial emboli this led to necrosis of the bone and subsequent displacement of the affected area into the joint This theory has met much resistance and has not been widely accepted

Barth supported the traumatic theory and *noted that loose bodies regardless of* their origin, when associated with arthritis assume features similar to those of arthritic loose bodies

Of interest was the conception of origin of loose bodies in the knee joint proposed by Ludloff He was of the opinion that the arteria genu media was an end artery supplying the region of the medial condyle usually involved in osteochondritis dissecans also that this vessel was injured before it perforated the bone in the region of the insertion of the posterior cruciate ligament Constant traction on the posterior cruciate ligament was believed to be the agent responsible for injury to the vessel The circulation to the area normally supplied by the vessel is impaired resulting in necrosis of the bone and overlying cartilage and eventual extrusion of the fragment into the joint cavity

It has been proved that the arteria genu media is not an end artery also injury to *a vessel by soft tissue traction* is most unlikely to occur This premise fails to explain the development of the disorder in other sites

Some observers advanced the theory that some underlying constitutional disorder affecting bone and cartilage may be responsible for the formation of loose bodies in joints Fromone expressed this view he assumed that the loose bodies were the product of partial fractures or continued stress on the affected areas There abnormal forces were responsible for the development of zones of transformation followed by separation of the fragment Subsequent traumata complete the separation allowing the loose bodies to drop into the joint cavity Bilateral involvement of the knees is given in support of this concept

Critical assessment of the varied theories advanced by numerous investigators fails *to provide an explanation for the origin of*



Fig 315 (*Left*) Osteochondritis dissecans of the lateral femoral condyle (*Right*) Two bodies were found in the joint and a large defect in the lateral condyle *The suprapatellar bursa* was thickened markedly and covered with numerous villi an incomplete synovectomy was performed

loose bodies under discussion, which is supported by indisputable clinical and scientific observations Although most investigators feel that trauma, in some form or manner, plays a significant role, no foolproof mechanism has yet been conceived Phemister offered the most plausible explanation He points out that articular cartilage is devoid of nerve supply, and that there is little sensation in the subchondral bone In the light of this information, it is possible for trauma to produce an incomplete subchondral fracture without clinical manifestation of sufficient severity to focus the attention of the patient on the incident Most of the cases occur in youth and early adult life when the individuals are exceedingly active and engage in rigorous endeavors, so that it is reasonable to assume that the aforementioned injuries may be sustained without knowledge of the patient or they were considered as insignificant and may be forgotten promptly Failure of subchondral fractures to unite needs further investigation It is possible that many do unite and never come to the attention of the individual This is purely speculative, on the other hand, some evidence has been offered that osteochondritis dissecans may occur and heals spontaneously

If the original lesion is an incomplete subchondral fracture resulting from single or repeated traumata, several factors may be responsible for the resulting nonunion and eventual separation and extrusion of the affected area into the joint Nonunion would be enhanced by the impaired circulation of the incompletely severed segment consisting of cartilage and subchondral bone in addition, the shearing strains incident to normal joint function would preclude normal healing between the parent bone and the fragment also, subsequent repeated traumata would favor nonunion Absorption of bone on the opposing surfaces is characteristic of all fractures, in the case in point, any remaining osseous tissue between the two surfaces would undergo dissolution Both raw surfaces are finally covered by a layer of mature connective tis-



FIG 316 Osteochondritis dissecans of the patella in a boy 16 years old. Note that the loose body still lies in its niche in the articular surface of the patella which already shows some incongruity (*Left*) Lateral view (*Right*) Tangential view of the patella.

sue which takes on characteristics consistent with fibrocartilage Elimination of some or all of these factors may be responsible for healing of the lesion in some cases treated by complete and prolonged immobilization

The theory of occlusions of end arteries by clumps of bacteria or fat is untenable because no reasons are advanced to explain why *certain end arteries should be the site* of predilection and not others

Some clinical observations have been recorded which suggest the existence of some constitutional disturbance in the cases under discussion Familial tendencies and instances of bilateral and multiple lesions have been noted Nevertheless the accumulated clinical and other data are not sufficient to justify acceptance of this concept without further investigation

PATHOLOGY

In the majority of cases the lesion is found in the lateral aspect of the medial femoral condyle close to or involving the area of insertion of the posterior cruciate ligament Occasionally, the bodies arise from the articular surface of the lateral condyle of the femur (Fig 315) the patella, (Fig 316) and in very rare instances from the tibia As a rule one area in the knee joint is implicated this may give rise to one or several loose bodies the number of bodies rarely exceeds three

If the body is still attached its cartilaginous surface is soft often fibrillated and exhibits a yellowish color Usually a line of separation is discernible between the parent bone and the fragment In such instances the loose body can be shelled out of its bed readily The author has observed several cases in which no break in the continuity of the articular surface was present the only gross evidence of the lesion was some softening and slight *discoloration of the in*volved area In one instance the lesion was demonstrable by roentgenograms but on exploration of the joint the articular cartilage

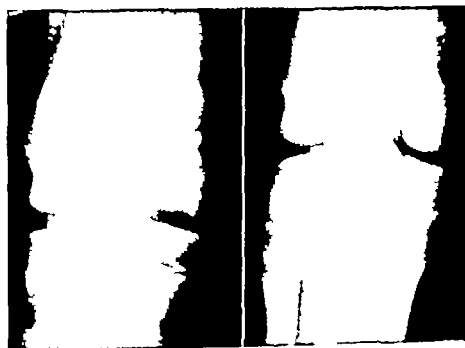


FIG 317 (*Left*) Osteochondritis dissecans of the medial femoral condyle in a boy 13 years old In spite of the extensive lesion noted in the roentgenograms exploration of this joint failed to reveal evidence of a pathologic process implicating the area depicted in the roentgenograms This patient was treated by immobilization of the limb in plaster for 5 months (*Right*) Note healing shown in roentgenogram taken 9 months later

appeared to be normal in every respect, there was no external evidence of an active pathologic process (Fig 317) Usually, the raw surface of the fragment is attached to its bed by a pedicle of fibrous tissue. When the body is enucleated, one notes that the opposing raw surfaces are covered with fibrous tissue and fibrocartilage While the loose body still remains in its niche in the parent bone and still retains some attachment by a pedicle, regenerative processes are active, however some degenerative alterations are also noted

The regenerative changes comprise (1) varying amounts of new bone formation along the line of separation where cancellous bone is present—the old osseous elements may be completely replaced by new bone—and (2) an abundance of fibrocartilage along the line of cleavage between the main bone and the loose fragment. During this period degenerative alterations in the bone and the articular cartilage may be minimal in intensity

With complete severance of all attachments, the loose body exhibits marked degenerative abnormalities The osseous tissue new and old undergoes necrosis also The articular cartilage exhibits further progression of necrosis and calcification The connective tissue and the fibrocartilage covering the raw surface draw sufficient nutrition from the synovial fluid to sustain the proliferative process, this results in a gradual increase in size of the loose body Over a long period of time, the articular cartilage and the bone are replaced slowly by the fibrocartilage subsequent calcification of the fibrocartilage produces a bizarre type of new bone The loose bodies eventually may come to rest in the suprapatellar pouch in the intercondylar notch in front of the anterior cruciate ligament or they may gravitate into the posterior compartment of the joint. Occasionally, they move about in the joint and produce symptoms of internal derangement

Bodies produced by a single injury which are comparable with complete subchondral fracture with displacement of the fragments into the joints behave differently than those formed by the process osteochondritis dissecans. In the former, a fresh, raw surface is always present at the line of separation. This facilitates attachment of the fragment to the synovial membrane in a recess of the joint, and here it develops a pedicle which supplies it with nutrition, or it may be enveloped by fibrous tissue or synovialis In experiments on animals by Phemister and others in which pieces of bone and cartilage were first removed and then reintroduced into the joint of the animal, the loose bodies became reattached in all instances After a few months they were absorbed and disappeared completely in uncomplicated cases

The disorder is limited to the affected area of the articular cartilage, the rest of the joint reveals no gross or microscopic evidence of pathology Frequently a tear of the medial meniscus is an associated finding this may be responsible for repeated episodes of locking followed by effusion In such instances a low-grade synovitis may be present and in old lesions varying degrees of osteoarthritic alterations may be observed This is also true in cases in which free loose bodies produce repeated incidences of giving way and momentary or true locking of the joint

Clinical Manifestations

The disorder usually is observed in late adolescence or in early adult life, only rarely is it encountered past middle life In the author's series over 90 per cent of the cases were males. Generally one knee is implicated, in a small percentage of cases the lesion is bilateral The general health of the patient is usually excellent. In some instances a specific history of trauma to the affected knee, either direct or indirect in nature, can be elicited However, in a large percentage of cases no such history can be obtained

No specific clinical manifestations are pathognomonic of this lesion the character

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With complete severance of all attachments, the loose body exhibits marked degenerative abnormalities The osseous tissue new and old undergoes necrosis also The articular cartilage exhibits further progression of necrosis and calcification The connective tissue and the fibrocartilage covering the raw surface draw sufficient nutrition from the synovial fluid to sustain the proliferative process, this results in a gradual increase in size of the loose body Over a long period of time the articular cartilage and the bone are replaced slowly by the fibrocartilage subsequent calcification of the fibrocartilage produces a bizarre type of new bone The loose bodies eventually may come to rest in the suprapatellar pouch in the intercondylar notch in front of the anterior cruciate ligament or they may gravitate into the posterior compartment of the joint Occasionally, they move about in the joint and produce symptoms of internal derangement.

Bodies produced by a single injury which are comparable with complete subchondral fracture with displacement of the fragments into the joints behave differently than those formed by the process osteochondritis dissecans In the former, a fresh, raw surface is always present at the line of separation This facilitates attachment of the fragment to the synovial membrane in a recess of the joint, and here it develops a pedicle which supplies it with nutrition or it may be enveloped by fibrous tissue or synovialis In experiments on animals by Phemister and others in which pieces of bone and cartilage were first removed and then reintroduced into the joint of the animal, the loose bodies became reattached in all instances After a few months they were absorbed and disappeared completely in uncomplicated cases

The disorder is limited to the affected area of the articular cartilage, the rest of the joint reveals no gross or microscopic evidence of pathology Frequently, a tear of the medial meniscus is an associated finding this may be responsible for repeated episodes of locking followed by effusion In such instances a low-grade synovitis may be present, and in old lesions varying degrees of osteoarthritic alterations may be observed This is also true in cases in which free loose bodies produce repeated incidences of giving way and momentary or true locking of the joint

Clinical Manifestations

The disorder usually is observed in late adolescence or in early adult life, only rarely is it encountered past middle life In the author's series over 90 per cent of the cases were males Generally one knee is implicated in a small percentage of cases the lesion is bilateral The general health of the patient is usually excellent. In some instances a specific history of trauma to the affected knee, either direct or indirect in nature can be elicited However, in a large percentage of cases no such history can be obtained

No specific clinical manifestations are pathognomonic of this lesion the character

of the clinical features is governed by the position and the size of the loose body. Most patients are aware of some vague pain in the joint which is accentuated by activity and relieved by rest. Frequently the bouts of pain are accompanied by varying degrees of swelling. These features are usually observed in patients in which the affected area of the articular cartilage still remains in its niche in the parent bone. If a lesion of the meniscus is present the symptoms of giving way or locking of the knee joint manifest themselves and render a diagnosis more difficult. Vague pain accentuated by activity and associated with recurrent effusions in the knee joint of an adolescent male should suggest the possibility of osteochondritis dissecans. The body may be in its niche but may be extremely mobile being held in place by a loose fibrous attachment. In such cases the mobility of the body is sufficient to permit momentary trapping of the fragment between the articular surfaces. This is accompanied by swelling and severe pain in the joint. The episodes tend to increase in intensity until the fragment is extruded into the joint.

The clinical picture is closely associated with the behavior of the loose body. In the event that it becomes detached either spontaneously or by some form of trauma, the patient may complain of giving way or momentary locking of the knee joint followed by effusion. The patient may volunteer the information that something moves about in the knee. If the body becomes trapped between the articular margins of the joint and the capsule a hard bony mass may be palpable at the joint margin. Repeated incidences of this nature occur until the free body becomes attached to the synovial membrane. When this occurs the symptoms disappear. The body may develop a pedicle at its new site of attachment allowing it sufficient mobility to be trapped momentarily between the articular surfaces. On the other hand if the loose body fails to attain an attachment to the lining of the joint or if it loses its attachment and again becomes freely mobile, the features of internal derangement manifest themselves. The symptoms produced by small loose bodies are more acute and occur more frequently than those caused by larger bodies because the former are more likely to be caught between the articular surfaces. Repeated episodes of giving way and effusion may cause varying degrees of laxity of the quadriceps mechanism, synovitis and in patients past middle life osteoarthritis of varying severity.

Physical examination invariably reveals some atrophy and loss of tone in the quadriceps muscle. If the patient is examined immediately after an episode of locking and effusion swelling is demonstrable particularly in the suprapatellar pouch. On several occasions the author has been able to feel the body at the articular margins of the joint. In the event that the body has been liberated from the articular surface of the patella, soft crepitus can be felt in the patellofemoral joint during flexion and extension of the knee; occasionally the crepitus is audible. In these cases if the patella is pressed firmly against the articular surface of the femur pain is elicited. As recorded previously the greater majority of loose bodies in the knee joint arise from the medial femoral condyle; in these cases with the knee flexed beyond a right angle firm digital pressure over the end of the condyle produces exquisite tenderness. Occasionally if the fragment has already been extruded into the joint and the defect in the condyle is large the incongruity in the articular surface may be palpable.

ROENTGENOGRAPHIC STUDIES

In cases of long standing roentgenographic study invariably establishes the diagnosis. Roentgenograms not only locate the position of the body in the joint but also depict the crater or niche in the femoral condyle or [illegible] a from which the loose body or [illegible] very early cases roentgeno[illegible] to reveal any evidence

of abnormalities in the articular surfaces In addition, if the detached fragment is composed entirely of cartilaginous tissue without calcification, roentgenograms will not provide information relative to the true nature of the lesion It is impossible to determine the actual size of a free body by roentgenograms. Not infrequently a large cartilaginous body may reveal only a thin line of calcification in these cases exploration discloses that the true size of the body is many times that depicted by roentgenograms (Fig 318) On the other hand the roentgenograms may show a wide zone of absorption in the cancellous bone between the parent bone and the affected overlying area and yet on exploration the cartilage is intact and may exhibit no evidence of pathologic changes (Fig 317)

Management

It is generally accepted that freely mobile bodies in the knee joints should be removed. The optimum time for their removal is before irreparable damage is suffered by the supportive structures of the joint and before alterations consistent with osteoarthritis are manifest. If the bodies are permitted to remain in the joint for long periods of time, during which repeated incidences of locking, giving way and effusion occur, the complications of chronic villonodular synovitis and eventually osteoarthritis are certain to follow (Fig 315) In such cases, removal of the bodies will relieve the acute manifestation, but it is not expected to be followed by complete relief of all symptoms resulting from the unfavorable sequelae established In addition, the presence of mobile bodies is hazardous to the patient not only while executing athletic pursuits but also in the course of his occupation and ordinary daily activities, locking may occur at inopportune occasions. It becomes apparent that removal of the bodies is most desirable.

Many observers are of the opinion that areas of osteochondritis dissecans which have not yet been separated but give rise to symptoms should be excised This method of management is challenged by some investigators who provide evidence in support of their views The former group contend that loose bodies even when not completely detached are responsible for repeated incidences of synovial reaction and

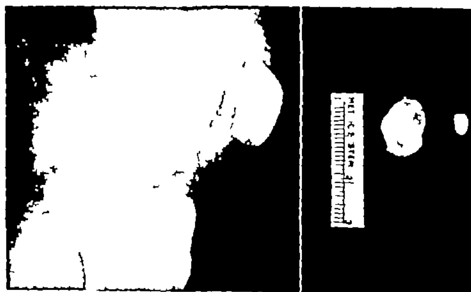


Fig 318 Osteochondritis dissecans of the knee joint of a male 36 years old The anteroposterior view fails to show the body (*Left*) The lateral view reveals a thin flake of calcified material (*Right*) The true size of the body A second small body also was found, both originated from the articular surface of the patella.



FIG 319 (*Left*) Osteochondritis dissecans in an adult male 32 years old Note the dense sclerotic loose body lying in a crater in the medial femoral condyle Such bodies should be removed. (*Right inset*) The loose body removed in this case, showing the articular surface being surrounded by a ridge of fibrous tissue.

tend to weaken the quadriceps apparatus which in turn makes the remaining supporting tissues vulnerable to injury For these reasons they advocated removal of the affected area before detachment is complete On the other hand the second group of workers provide evidence to show that not all the joints return to normalcy after the affected areas are excised from the ends of the bones The crater left behind may be a source of chronic irritation to the joint tissues allowing degenerative changes to progress in intensity In addition some clinical evidence has been offered which indicates that some cases of osteochondritis dissecans heal spontaneously Wiberg (1943) reported 6 cases of osteochondritis dissecans in children in which spontaneous healing occurred He concluded that conservative measures were indicated and should be instituted in patients up to the age of 16 or 17 years and in some cases up to 20 also that if during the period of treatment the fragment became detached it should be removed Surgical intervention should be reserved for cases after the age of 20 and only in earlier cases when definite indications were present Since the report of Wiberg several other workers have recorded revascularization of the undisplaced fragment in growing children when treated by conservative methods The author has 6 such cases in his files in 2 other cases separation occurred in spite of conservative treatment. However, it must be admitted that in the two latter cases the patients were both over 15 years of age—one was 16 and the other 18 Smillie reports one case in which he first detached the fragment and after drilling the base of the defect and the opposing surface of the fragment he replaced it in the crater revascularization of the body ensued and healing was demonstrable roentgenologically 4 months after the operation

In the light of the aforementioned observations the author is of the opinion that in growing children in which reparative processes are at a high level, osteochondritis dissecans without separation of the fragment should be given a trial of conservative treatment In adults usually different circumstances prevail generally the lesions are long standing the loose body is avascular and often sclerotic and covered by dense connective tissue Likewise the crater in the articular surface is sclerotic and lined by a mature fibrous tissue membrane Conservative measures in such cases are doomed to failure here surgical intervention whereby the body is excised is the treatment of choice (Fig 319)

Conservative Management. This comprises the application of a nonpadded plaster cylinder from above the malleoli to the

groin with the knee extended The patient is ambulatory and uses crutches The heel of the shoe of the opposite foot is elevated so that the foot on the affected side does not touch the floor Throughout the period of fixation the quadriceps muscle is exercised on a regulated regimen In most instances a new plaster cylinder is applied approximately every 4 to 6 weeks At the end of 3 months roentgenograms are taken to note the progress of healing if revascularization is demonstrable but healing is not complete immobilization is continued for 2 to 3 more months In the author s small series healing was achieved in 4 to 6 months On the other hand if the body becomes detached during this period surgical intervention is indicated

Case Report Case D J, aged 10 Negro The patient was admitted to the hospital because of recurrent episodes of pain and swelling in the left knee joint. This disorder had existed for 6 months prior to admission, there was no history of injury The pain was accentuated by activity and was relieved by rest.

Examination of the limb at the time of admission revealed some swelling of the knee joint and moderate atrophy of the quadriceps muscle. Motion was unrestricted in flexion or extension Pressure over the medial femoral condyle when the knee was flexed past a right angle elicited pronounced tenderness. Roentgenographic study of both extremities exhibited a small rarefied area on the medial aspect of the medial condyle of the left femur consistent with osteochondritis dissecans in the early stage of development (Fig. 320)

The limb was immobilized by a plaster cylinder no weight-bearing was allowed and quadriceps exercises were instituted At the end of 4 months, roentgenographic studies disclosed complete revascularization and healing of the affected area (Fig 320)

Surgical Management. Before the knee joint is opened it is essential to establish the precise location of the body Roentgenograms showing routine anteroposterior and



Fig 320 (*Left*) Early stages of osteochondritis dissecans in a male 10 years old (*Right*) Healing of the affected area after 4 months of immobilization in a plaster cylinder without weight bearing.

lateral views of the knee joint may fail to locate the true position of the defect in the articular condyles of the femur In addition to the routine lateral views, the lesion is demonstrated best by anteroposterior views taken with the knee in varying degrees of flexion In cases of osteochondritis of the patella tangential views may be necessary in order to show the lesion All surgeons who have removed loose bodies from the knee joint know of the elusiveness of these structures therefore it is important to have roentgenograms taken immediately before the operation is performed In order to preclude change of position of the loose body the position of the limb must not be altered after the final roentgenograms are taken Calcified bodies and those containing some osseous tissue are readily depicted however one must bear in mind that roentgenographic study may fail to reveal the presence of loose cartilaginous bodies hence a thorough search should be made of the region of the joint explored Also, those areas which are most likely to harbor the bodies should be investigated such as the intercondylar region and the suprapatellar pouch Small incisions to remove loose bodies without exploration of the defects from which they arose are not justifiable In many instances portions of the articular cartilage at the periphery of the crater are fragmented and loose failure to remove this defective tissue may result in the formation and separation of more loose bodies and recurrence of symptoms On the other hand unnecessary extensive exposure should not be employed routinely Long parapatellar incisions are not necessary to expose the medial or the lateral compartment of the knee joint when the lesion is localized to one of the femoral condyles However if coexistent pathology of the synovial membrane is present requiring partial synovectomy in addition to removal of a loose body then parapatellar incisions are indicated Before the wound is closed roentgenograms are taken with a portable unit to note whether or not all radiopaque bodies have been removed

The affected area of the articular surface demands particular attention the problems presented and their management vary in each case In the event that the body lies loosely in the defect it should be removed this is achieved best by a sharp curved gouge which readily scoops the loose fragment out of the niche After the main body is excised the articular cartilage bordering the defect often exhibits softening fibrillation and fraying The defective material is shaved off carefully in layers until normal cartilage is reached the edges of the crater are beveled Next attention is directed to the floor of the crater with a sharp curet all debris is removed from the floor of the defect until normal bleeding cancellous bone is exposed In cases of long standing the floor of the crater may be lined with dense sclerotic bone, in such cases the author first removes all loose connective tissue with a sharp curet and then perforates the dense layer of bone with numerous fine drill holes in an attempt to revascularize the sclerotic bone and to allow the crater to fill with blood It is hoped that this procedure will initiate the formation of fibrocartilage in sufficient quantities to obliterate the cavity

If the loose bodies lie at a distance from the cavity in the articular surface either free or attached to the synovial lining their removal is first effected and then the site of their origin is inspected and treated in accordance with the circumstances present Generally the cavity in the articular cartilage particularly in long standing cases is decreased in depth by the formation of varying amounts of connective tissue defective bone and fibrocartilage The articular cartilage immediately around the defect is soft and fibrillated In such instances the area should be treated in the manner described above

In youthful patients occasionally a situation is encountered similar to that of Case

E L (Fig 317) in which, in spite of the roentgenographic findings indicating separation of an osteocartilaginous body, visualization of the affected region fails to show grossly any evidence of pathologic alterations in the articular cartilage or only minimal changes may be demonstrable but no line of separation is discernible between the normal and the pathologic articular cartilage It is the author s opinion that in such instances *the articular area supposedly affected* should not be excavated but instead it should be left undisturbed, the wound closed, and conservative measures instituted In Case E L. revascularization occurred, and healing was complete at the end of 6 months It has occurred to the author that *in such cases fine drill holes transversing* the affected articular cartilage and the underlying bone may enhance revascularization and healing This has been tried in two cases, but sufficient time has not elapsed to determine the ultimate fate of loose fragments in these cases. In adults revascularization of loose fragments is not likely to occur All affected cartilage and underlying bone must be excised and the bed of the cavity should be curetted until normal bleeding bone is reached or it is perforated with multiple fine drill holes.

Surgical Approaches

Loose Bodies Arising from the Medial Femoral Condyle These bodies may lie in *the niche in the medial femoral condyle* or may be displaced into the anterior compartment of the intercondylar notch into the suprapatellar pouch or occasionally may even migrate to the posterior compartment of the joint (Fig 321) The bodies in the anteromedial compartment of the joint and *in the intercondylar notch are made readily* accessible through an anteromedial curved incision If access to the posteromedial compartment is desirable, this may be achieved by extending the posterior limb of the incision to a point 1 cm posterior to the medial



Fig 321 Osteochondritis dissecans of the medial femoral condyle. Several fragments still occupy a position in the crater in the condyle one body has migrated to the posteromedial compartment All these fragments were removed through a medial meniscal incision which extended slightly posteriorly to permit an incision into the posterior capsule behind the longitudinal fibers of the tibial collateral ligament.



Fig 322 A single loose body in the anterolateral compartment. It arose from the articular surface of the patella and was removed through a lateral para patellar incision.

epicondyle of the femur A second capsular incision is made behind and parallel with the longitudinal fibers of the superficial por tion of the tibial collateral ligament This allows ample exposure of the posterior com partment of the joint this incision is usu ally employed to remove the posterior seg ment of the medial meniscus but it also affords ready access to loose bodies in the posteromedial compartment.

Loose Bodies Arising from the Lateral Femoral Condyle The surgical management of these bodies is similar to that of the bodies arising from the medial femoral con dyle An anterolateral curved incision is em ployed to expose the anterolateral compart ment Extension of this incision posteriorly permits access into the posterolateral com partment

The suprapatellar pouch should be in spected for the presence of bodies not de picted in the roentgenograms. In order to perform this adequately the limb must be extended at the knee thereby relaxing the extensor apparatus then a careful digital examination of the pouch is made Also re peated flexion and extension of the joint are performed at this time these maneuvers may bring into view loose bodies not de monstrable by roentgenographic studies Before the wound is closed the joint is flushed thoroughly with a solution of sterile saline this removes small particles of carti lage bone and fibrous tissue

Loose Bodies in the Suprapatellar Pouch Bodies in this region are usually accessible through the anteromedial or anterolateral incisions As a rule, with the knee extended a digital examination will locate the loose body in the pouch or it can be maneuvered into the anterior compartments of the joint However, in cases accompanied by advanced chronic villous synovitis which necessitates a partial or more extensive synovectomy then a medial parapatellar incision should be utilized

Loose Bodies Arising from the Patella It is desirable to inspect the undersurface of the patella when it is apparent that this is the source of the loose body The articular surface of the patella is best brought into view by the medial or the lateral parapatel lar incisions Figure 322 depicts a loose body in the anterolateral compartment of the joint which arose from the articular sur face of the patella The body was removed and the patellar surface was inspected through a lateral parapatellar incision. A large crater barely suggested by the roent genograms was encountered

Loose Bodies in Posterior Compartments As recorded previously the posteromedial and the posterolateral compartments may be exposed through the extended posterior limb of the meniscal incisions On the me dial side the posteromedial capsular incision is made behind the long fibers of the tibial collateral ligament on the lateral side the posterolateral capsular incision is made be hind the fibular collateral ligament Occa sionally it may be desirable to limit the exposure to the posteromedial or the pos terolateral aspect of the joint In such cases the posteromedial and the posterolateral in cisions of Henderson will provide the desired

exposure these incisions are especially useful for removal of loose bodies from the posterior compartment. Occasionally, the midline incision on the posterior aspect of the knee may be employed.

Postoperative Management. When the anteromedial or the anterolateral incisions are employed the postoperative management is essentially similar to that described for meniscectomy However, there is some variation At the termination of the operation an elastic compression bandage is applied extending from the mid-calf to the mid thigh The limb is put at complete rest in order to preclude filling of the joint with blood from raw bony surfaces. In the event that such filling should occur, aspiration is indicated Immobilization is continued for 2 to 3 weeks, depending upon the intensity of the joint reaction At the end of this period quadriceps drill and flexion exercises are instituted Weight bearing is not permitted before 3 weeks postoperatively From this point on, the problem is one of redevelopment of the quadriceps mechanism to the maximum level of efficiency

When simple removal of the bodies was performed through posteromedial posterolateral or posterior mid line incisions, rehabilitation is not delayed but commenced immediately after the operation

OSTEOCHONDROMATOSIS

Osteochondromatosis is now recognized as a specific clinical entity in which the synovial membranes of joints and less frequently of bursae and tendon sheaths give rise to cartilaginous and osteocartilaginous bodies Other designations for this disorder are synovial chondromata diffuse enchondroma of the joint capsule and joint chondromata At first the bodies are attached to the synovial membrane by a pedicle later they are extruded into the joint cavity the bursa or the tendon sheath. These bodies differ from those encountered in osteochondritis in that they are formed by the synovial membrane and are in no way related to the articular ends of the bones, moreover, the bodies comprise organized tissues setting them apart from "rice bodies (corpora oryzoidea) which are composed of unorganized tissues.

Historical Review and Etiology

Loose cartilaginous bodies have attracted the interest of many investigators. Laennec (1813) is credited with the first description of the disorder and was of the opinion that the bodies were the products of the subsynovial tissues At this time most observers believed that the bodies arose from coagulated lymph effused from the synovialis the process involved being one of vascularization of the lymph coagulum

In 1836 Brodie proposed the theory which is in agreement with the concept held by many observers of the present day He recorded that the cartilaginous bodies arose on the external surface of the synovialis or within its substance Macartney (1841) noted that at first the bodies were attached to the synovial membrane by pedicles which contained blood vessels and that rupture of the pedicles set the bodies free in the synovial cavity At about this time (1848) Rainey proposed the premise that a type of synovial membrane exists containing certain cells which, when influenced by morbid action (inflammation), are capable of secreting cartilage which later may be converted into imperfectly formed bone The newly formed bodies retain a vascular pedicle which supplies nutrient for their growth and development

Kolliker in 1851, observed that synovial membrane or outgrowths of this structure contained cartilage cells which gave rise to the cartilaginous bodies these at first increased in size and later became detached from their pedicles and set free in the synovial cavity The work of Kolliker was followed by numerous articles in the literature in which some explanation was offered for the formation of the loose bodies by the

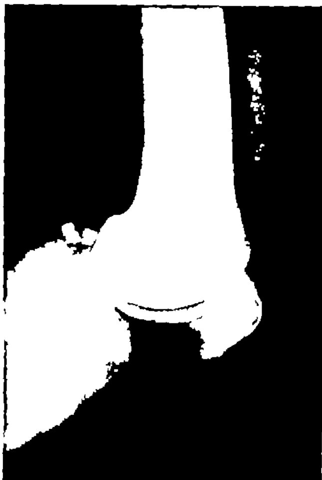


Fig 323 Osteochondromatosis of the knee joint. The loose bodies have gravitated to the posterior compartment. The synovialis elsewhere in the joint and the articular cartilage were normal grossly and microscopically



Fig 324 Osteochondromatosis of the elbow

synovial membrane trauma and infection were etiologic factors believed to play a major role in the formation of the cartilaginous structures. The first report in the American literature was recorded by Henderson in 1916 this worker adopted the name synovial osteochondromatosis Since this report numerous other American writers have recorded their findings and views

In 1921 Fisher attempted to group cases of synovial osteochondromatosis into those associated with osteoarthritis and those not associated with osteoarthritis He believed however that the bodies in the two groups exhibited similar macroscopic and microscopic features This observer was of the opinion that the etiology of this malady was associated closely with the etiology of tumors and pointed out the close relationship which the tissues of the two disorders bear to one another from an embryologic viewpoint.

Freund in 1937 recorded his views on the etiology of osteochondromatosis, he regarded the pathologic process as a metaplasia of the synovial connective tissue similar to myositis ossificans and parosteal ossification and chondrifications The known potentiality of the mesodermal tissues to form bone and cartilage by the process of metaplasia was the basis for this observer s concept This view is now in agreement with the more popular theory which places the process in the same category as benign neoplastic lesions

From this brief historical survey it becomes apparent that the etiology of osteochondromatosis is not definitely established However the two most popular theories which prevail at the present time are (1) the concept which proposes that the lesion is comparable with a benign neoplastic process implicating the synovial membrane and (2) the view which attributes the formation of the cartilaginous bodies to a process of metaplasia of the connective tissues of the synovial lining

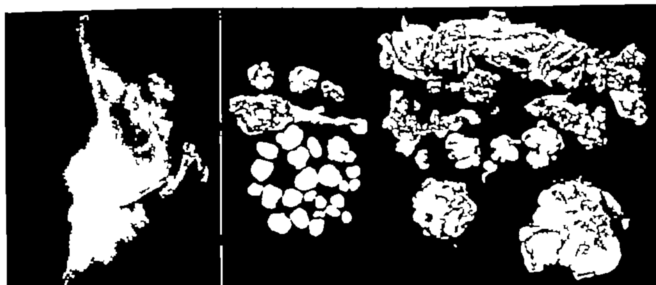




FIG 325 (*Top*) Right knee of a patient 48 years old (*Left*) Note the large coarse bodies in both the suprapatellar pouch and in the posterior compartment. The articular surfaces of the patella, the femur and the tibia exhibit evidence of osteoarthritic alterations. This patient had a similar process with numerous bodies in the left knee joint. (*Right*) Loose bodies and portions of the synovial membrane were removed in this case.

FIG 326 (*Bottom*) Osteochondromatosis in a patient 72 years old Osteoarthritic changes are demonstrable in the patellofemoral and the femorotibial joints.

Likewise, the agents initiating the pathologic process have not been determined trauma, infection and embryonic rests—all have been offered as possible factors

PATHOLOGY

The number of bodies vary from a few to several hundred also, they vary considerably in size. Usually they are round or oval exhibiting a smooth or faceted surface some are pitted and irregular in form (Fig 323) Generally, one joint is involved but in rare instances more than one joint may be implicated the disorder is encountered most frequently in the knee joint The elbow joint is involved next in the order of frequency (Fig 324) As noted previously, bursae and tendon sheaths may be affected, although the incidence is relatively low Males are affected more frequently than females Although trauma as an initiating factor is debatable, it is significant to note that the lesion usually affects those joints most vulnerable to trauma and joints subjected to great stress and strains during normal function this applies particularly to the knee and the elbow joints Mussey and Henderson reported an incidence of 70 per cent in the knees and 22 per cent in the elbows On the other hand, the trauma may serve only to focus the attention of the patient to the affected joint in which the lesion is already long standing. Some of the bodies may become encysted in the synovial



FIG 327 (*Top*) Osteochondromatosis in a patient 33 years old The synovial membrane showed proliferative activity numerous bodies in all stages of formation were found The synovial membrane was studded with hundreds of cartilage bodies Note that the amount of calcification in the bodies depicted in the roentgenograms is minimal. (*Bottom*) Osteochondromatosis Observe the cartilaginous bodies forming in the synovial membrane also the hyperplasia and the villous formation of the synovialis.

membrane or may be in a pouch in the membrane It appears as though the bodies while increasing in size slowly distend the synovial lining and capsule to form out pouchings from the joint cavity In the knee joint many bodies tend to gravitate into the posterior compartment (Fig 325) However some are found in the suprapatellar pouch and in the intercondylar region (Fig 326)

The pathologic process in the synovial lining pursues a constant clinical course It is self limited and according to Freund the bodies may disappear this observation has been noted by other workers It appears that the disease runs a specific cycle at the termination of which the synovial membrane returns to normalcy In most instances by the time the diagnosis is definitely established and surgical intervention instituted little or no activity is discernible in the synovial membrane Occasionally a joint is encountered in which part or all of the synovialis exhibits proliferative activ

ity cartilaginous bodies are observed in all stages of formation (Fig 327) In cases of long standing the synovial membrane appears to be grossly similar to chronic synovitis observed in traumatic or degenerative arthritis In early cases the articular cartilage exhibits no macroscopic abnormalities In more advanced cases evidence consistent with osteoarthritis is manifest (Figs 325 and 326) implicating the articular cartilage The subchondral bone generally discloses no alterations The hypothesis claiming that the disorder is a benign neoplasm is supported by the work of Jones (1927) who observed that the development of these bodies pursues the same stages encountered in the embryonic formation of cartilage previously described by Keibel and Mall This observer noted that the cartilaginous bodies originated in the synovialis directly from the lining cells which are modified fibroblasts Generally the bodies arise in the synovialis per se and only occasionally in the subsynovial tissue Subsequently, the growing bodies become calcified or even ossified On occasion, bone may originate directly from the fibroblasts As the bodies form in size they assume a more superficial position and eventually are held in position by a pedicle Finally, with severance of the pedicles the bodies are liberated into the joint The free bodies exhibit living cartilage cells at their peripheries nourishment being obtained from the synovial fluid However the bone in the center of the body which is deprived of all nourishment dies

The microscopic appearance of the loose bodies depends upon the size and the stage of development. During the early stages the bodies are small consisting entirely of cartilage cells which exhibit a specific pattern in a hyaline matrix The bodies usually are attached to the synovial membrane by a vascular pedicle As the bodies increase in size calcification is demonstrable in their center later the calcified cartilage is replaced with imperfect bone which may proliferate, provided that the bodies retain their attachment to the synovial lining The bodies are now osteocartilaginous structures Larger bodies which lose their attachment may show some proliferation of the cartilage cells near the surface, while the deeper tissues undergo degenerative alterations These alterations comprise irregular areas of calcification in the cartilaginous elements and necrosis of bone the outer surface of the body may be partly covered by imperfectly formed or degenerating fibrocartilage

Clinical Features

Many of the patients are unable to recall any form of trauma which might be associated with the clinical manifestations of the disease, Mussey and Henderson recorded that only one third of the patients with affected knees recalled trauma Generally, the onset is insidious in nature, or the patient's attention may be focused to the knee by some unrelated trauma. At first the patient notices slight discomfort, weakness and some restriction of motion in the affected knee Later these symptoms become more pronounced but rarely are of sufficient intensity to cause great dysfunction Giving way and momentary locking of the joint may occur these incidents may be accompanied by pain, stiffness and swelling of the joint. Pain is rarely severe except when locking of the joint occurs Many patients are aware of the presence of loose bodies in the joint and often state that occasionally they can actually palpate the freely movable masses In some cases it is interesting to note the number of bodies that can occupy a joint and still produce only minimal symptoms Case C S (Fig 325) illustrates this point. This patient had both knees implicated and numerous bodies of varying size and shape were removed (Fig 325) In addition, moderate osteoarthritic changes were demonstrable in the joint yet this patient exhibited only mild discomfort and minimal dysfunction



Fig 328 Osteoarthritis and osteochondromatosis of the knee joint Note the spurring of the patellar poles and the anterior articular surface of the femur Osteoarthritis may have antedated the occurrence of osteochondromatosis or it may be the result of the mechanical irritation produced by the loose bodies

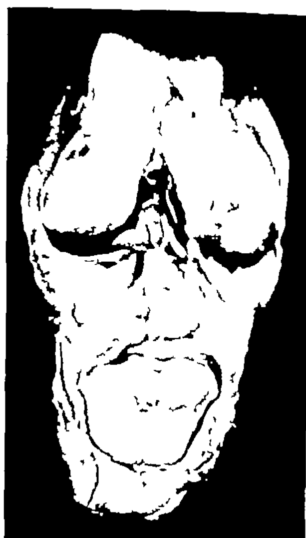


Fig. 329 Advanced osteoarthritic changes implicating all the articular surfaces and the margins of the patella and the margins of the femoral condyles. Note the formation of osteophytes varying in size which may be detached readily by some form of trauma.

Physical findings may not be significant mild forms of the disease No swelling or nitation of motion may be discernible e bodies may not be palpable The only ue to the disorder may be the patient s story of momentary locking or that on casion he is able to palpate a movable dy in the joint

In more advanced involvement some elling and pericapsular thickening may be monstrable The quadriceps reveals vary g degrees of atrophy some limitation of otion is usually present although the tent of the dysfunction is rarely severe hen large numbers of bodies occupy the prapatellar pouch the structures are readily palpable and can be moved about in the distended synovial cavity

Roentgenographic Findings

In cases of long standing the bodies usually are sufficiently calcified and contain enough osseous tissue to render them visible in the roentgenograms However it is generally known that bodies consisting entirely of cartilage are radiolucent It becomes apparent that in the early stages of development many cartilaginous bodies may be present and still the roentgenograms may

fail to disclose their presence The size of the bodies cannot be determined by roentgenographic studies because only the calcified and osseous tissues are visible Mechanical irritation to the joint over a long period of time results in osteoarthritic abnormalities these, when present, are readily discernible by roentgenographic study (Fig 328)

DIAGNOSIS

Little difficulty is encountered in establishing a diagnosis when roentgenographic studies disclose the presence of large numbers of bodies When only a few bodies are present the diagnosis may be more difficult, particularly in the presence of osteoarthritis, because they may be detached osteophytes produced by some form of trauma or they may be the product of osteochondritis dissecans of the articular ends of the bones Although instances of single bodies resulting from osteochondromatosis have been recorded this is difficult to establish as a clinical fact because it is generally known that loose bodies from other sources may first become detached and later achieve a secondary attachment to the synovial lining so that they are indistinguishable from bodies arising primarily from the synovial membrane In some cases of osteochondromatosis the synovial membrane may return to normalcy after the formation of the osteocartilaginous bodies This observation renders even more difficult the recognition of the true nature of the bodies when they are few in number However, the presence of features consistent with osteoarthritis or the presence of a defect in the articular surfaces of the femur, the tibia or the patella may shed some light on the origin of the bodies (Fig 329)

Occasionally loose bodies may arise from repeated injury to one of the menisci (Fig 330) Here the clinical manifestations of a loose body may be superimposed upon those of a tear of the meniscus. The classical signs and symptoms of a meniscal lesion are usually present, moreover, bodies arising from this source are usually radiolucent unless secondary calcification has occurred



FIG 330 Medial meniscus in a male 23 years old Two bodies were found free in the joint and one was attached to the anterior cruciate ligament. Apparently, all 3 fibrocartilaginous bodies originated from the central segment of the longitudinal tear repeated trappings of this segment were responsible for the formation of the bodies (*Left*, superior surface, *right* inferior surface)

Finally, the disorder must be differentiated from rice bodies (corpora oryzoidea) These are usually by-products of chronic inflammatory processes of the synovial membrane, such as in chronic synovitis or tuberculosis, they are not radiopaque As a rule, the history of the case, the clinical features and the microscopic findings establish the diagnosis

MANAGEMENT

Loose bodies in the knee joint should be removed because they are capable of producing mechanical derangement of the joint leading to osteoarthritis When these occupy the suprapatellar pouch or are located

in the intercondylar notch their removal is facilitated by one of the parapatellar incisions. These approaches permit adequate inspection of the suprapatellar pouch and the anterior compartment of the joint *When the bodies are situated in the posterior compartments of the joint the mid line* incision on the posterior aspect of the knee or the posteromedial and the anterolateral *incisions of Henderson may be utilized* The latter two incisions are particularly valuable when only a limited exposure is desired If the pathologic process in the synovial membrane is still active or if the synovialis exhibits secondary alterations such as villous synovitis synovectomy should be performed In the knee a large portion of the synovial lining can be removed however the lining in the posterior aspect of the joint is not readily accessible Occasionally when bodies are situated in both the anterior and the posterior recesses of the knee joint two approaches are necessary to remove *all the bodies* This *may be executed* at one operation or the posterior compartment may be explored at a second operation *Exploration of the joint may fail to* locate some of the bodies visualized by roentgenograms In such instances the bodies may be *located in bursal sacs or* diverticuli of the joint cavity or they may be encysted within the synovial membrane A thorough search must be made in such instances and the bursal sac or pouch should be excised together with the bodies

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PROGNOSIS

After all the bodies are *removed and if* the synovial membrane is no longer active in the production of bodies good results can be anticipated so far as the formation of more bodies is concerned The amount of residual dysfunction *depends upon the absence* or the presence of osteoarthritic changes at the time of surgical intervention *provided that the pathologic process in th* synovialis is no longer active When the former circumstances exist the results *should be excellent* When the latter circumstances prevail the degree of dysfunction is governed by the severity of th osteoarthritic alterations In these cases removal of the bodies together with partial or complete synovectomy will not only eliminate the chief causes of mechanical derangement of the joint but also will prevent further trauma to an already impaired joint

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Prognosis

After all the bodies are removed and if the synovial membrane is no longer active in the production of bodies, good results can be anticipated so far as the formation of more bodies is concerned. The amount of residual dysfunction depends upon the absence or the presence of osteoarthritic changes at the time of surgical intervention, provided that the pathologic process in the synovialis is no longer active When the former circumstances exist, the results should be excellent When the latter circumstances prevail the degree of dysfunc*tion is governed by the severity of th*e osteoarthritic alterations In these cases removal of the bodies together with partial or complete synovectomy, will not only eliminate the chief causes of mechanical derangement of the joint but also will prevent further trauma to an already impaired joint

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Management

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Management

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dure is performed best through one of the parapatellar incisions preferably the lateral For removal of the bodies alone, the incisions employed are similar to those utilized to remove loose bodies associated with osteochondritis and osteochondromatosis

The postoperative management in these cases demands special emphasis A concerted effort should be made to develop the quadriceps apparatus to its maximum level of efficiency This protects the joint from added trauma which invariably results from a lax extensor mechanism and laxity of the ligaments and the capsule these are frequent concomitant features of osteoarthritis. In addition the patient should eliminate excessive and strenuous activities The demands made on the joint should not exceed its functional capacity

LOOSE BODIES OF TRAUMATIC ORIGIN

These include cartilaginous or osteocartilaginous bodies produced by some form of trauma and are comparable with subchondral fractures of the patella or of the femoral condyles and fractures of the tibial spines with detachment Subchondral fractures of the patella and fractures of the tibial spine have been discussed previously Immediately after their detachment the bodies present a raw surface at the site of their attachment to the parent bone they vary in size and configuration If they contain calcified material and osseous tissue the bodies are readily demonstrable by roentgenographic study on the other hand large cartilaginous bodies may be radiolucent In cases of subchondral fractures of the patella a small thin sliver of calcified material may be the only indication of a large cartilaginous body in the joint In recent cases the defect from which the body originates may be discernible roentgenographically

The ultimate fate of traumatic loose bodies, provided that they remain free and fail to attain a secondary attachment to the synovialis, is similar to that of other types of loose-body formation Also like other types, they may cause sufficient mechanical irritation in the knee joint to stimulate pathologic reactions culminating in osteoarthritis of varying intensity

Immediately after detachment the diagnosis is not difficult to establish There is usually a history of some type of violence to the knee joint, followed by effusion hemarthrosis and dysfunction Roentgenographic studies uncover the presence of radiopaque bodies in the joint and also may indicate the source of origin of the body In cases of long standing the clinical features are those of a loose body added to manifestations consistent with osteoarthritis of the knee joint.

Treatment of recent subchondral fractures and fractures of the tibial spines has been considered previously management of traumatic loose bodies residing in the knee joint for months or years is similar to that described for other types of loose bodies.

Loose Bodies Arising From Menisci

These may be considered as another type of traumatic loose bodies (Fig 330) Comprehension of the pathogenesis of these fibrocartilaginous bodies is facilitated when one realizes that repeated trappings of the central segment of a longitudinal tear may cut off small pieces of fibrocartilage from the main central portion of the meniscus. The clinical manifestations are those typical of a torn meniscus to which are added the features of loose bodies, provided that they are unattached in the joint Roentgenograms fail to show the bodies unless some calcification has occurred The goal of the treatment should be excision of the torn meniscus removal of the loose bodies and restoration of normal tone power and control of the quadriceps muscle

RICE BODIES (CORPORA ORYZOIDEA)

These are small, glistening, whitish bodies usually found in great numbers and have been likened to rice kernels or melon seeds They comprise unorganized fibrin or necrotic villi of a hyperplastic synovial membrane such as is encountered in chronic arthritis or synovitis and in tuberculosis of joints or tendon sheaths Occasionally, they may develop after hemarthrosis when they consist principally of unorganized fibrin the bodies sometimes show a laminated pattern

The bodies found in chronic synovitis or proliferative arthritis develop differently from those encountered in tuberculosis In the former, the tissue reaction is reflected in the response of the capsular tissues these may exhibit extensive cellular proliferation in all strata, including the synovialis which may display advanced villous formation The villi may become thickened and bulbous their vascular channels may become obliterated the villi now undergo necrosis and are exfoliated into the joint as free bodies Rice bodies occur in greater numbers in proliferative arthritis and synovitis than in tuberculosis (Fig 333)

Rice bodies arising in tuberculous joints comprise chiefly unorganized fibrin which is deposited on villi layer by layer Eventually, the villi are detached and dropped into the joint cavity As pointed out by Luck when the joint is in motion fibrin may be rolled up into small oval or rounded bodies

At first, rice bodies, no matter what their origin, may disclose frayed, irregular peripheries. Later they become smooth white glistening and assume a characteristic configuration resembling melon seeds.

OTHER VARIETIES OF LOOSE BODIES

For the sake of completeness, mention must be made of loose bodies associated with other joint disorders.

1 **Suppurative Arthritis.** Pyogenic infections of the knee joint may result in necrosis of some portions of the articular surfaces of the femur, the tibia or the patella In the wake of this tragedy loose bodies may be found in the joint in the form of segments of articular cartilage varying in size or necrotic pieces of bone covered with devitalized cartilage In cases of infection of the hip joint extrusion of the whole capital epiphysis may be encountered

2 **Neuropathic Joints.** Degenerative lesions of the central nervous system, such as those observed in syringomyelia and tabes dorsalis, frequently are accompanied by disintegration of one or more joints The knee is implicated more frequently than other joints Loose bodies are formed by severance of osteophytes or develop from synovial fringes Generally, they are larger than those encountered in other forms of loose bodies they vary in size in the same joint, are often irregular and may be free or attached to the synovial lining The diagnosis is readily established by the presence of a large boggy knee joint exhibiting abnormal mobility and giving rise to no pain The roentgenographic features are typical for this type of joint disorder these are discussed in the section dealing with neuropathic arthropathies

3 **Tuberculosis of the Knee Joint.** In advanced lesions sequestration of portions of the articular surface of the bone ends may occur the end of the femur is affected more frequently

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11

Affections of the Synovialis and the Bursae of the Knee Joint

The pathologic processes of the synovial membrane observed in proliferative and degenerative arthritis are not discussed herein these changes are considered in the next chapter which deals with arthritis of the knee joint Before we can treat synovidities intelligently comprehension of the structure, the functions and the peculiarities of the synovial membrane and the synovial fluid is essential

SYNOVIALIS

Most joint capsules consist of two layers (1) an outer layer comprising dense fibrous tissue and (2) an inner layer, composed of modified connective tissue, the synovialis. In the knee joint the external fibrous component of the capsule is deficient in the anterior aspect of the joint here the synovialis lies directly on the anterior surface of the femur and then is reflexed to the posterior surface of the quadriceps tendon forming the suprapatellar pouch Kling points out that a layer of fat intervenes between the synovialis and the anterior surface of the femur he designated this the posterior suprapatellar fat pad another similar fat pad is found between the quadriceps tendon and the synovialis (the anterior suprapatellar fat pad) The synovial membrane is more cellular than the outer layer and contains specialized cells which form mucin It terminates at the cartilaginous surfaces and possesses a rich blood supply The blood vessels lie immediately below the synovial lining and normally do not lie on the surface Also this delicate structure is endowed with rich lymphatic plexuses Fine nerve fibers accompany the blood vessels ending in terminal arborizations or end bulbs or plates In the layer immediately below the surface pacinian corpuscles are invariably present

Several variations of the synovial lining have been described The nature of the structure is determined by the character of the underlying tissues All types may be encountered in the same joint Key recorded these variations the areolar, the fibrous and the adipose

The areolar variation is located on loose connective tissue which is not subjected to strain or pressure and allows considerable mobility of the synovial lining Numerous villi are demonstrable they comprise projections of the areolar tissue which are invested in synovial cells The shape of the villi varies from fine single fingerlike structures to clusters of branching villi Essentially the synovial lining comprises collagenous fibers between which fibroblasts with processes of varying lengths are interspersed The fibroblasts do not form a continuous covering for the loose connective tissue This type is richly supplied with blood vessels lymphatics and medullated and nonmedullated nerve fibers

Those elements of the joints which are subjected constantly to strain during normal function such as tendons and intraarticular ligaments are covered by the fibrous variation of the synovialis. This

lining consists of dense connective tissue of which the outer surface is more cellular than the rest of the membrane. If subjected to unusual pressure and stress, this tissue assumes the characteristics of fibrocartilage

The adipose form of synovialis covers fatty tissue which projects into joint cavities, such as the fat pads of the knee joint. Normally, it comprises a delicate single layer of cells supported by a thin stratum of loose connective tissue

The synovial membrane may be thrown into folds when the joint assumes certain positions This is particularly true of the synovialis that lines the anterior and inferior aspects of the shoulder joint and the posterior aspect of the knee joint However these are only temporary folds which are obliterated readily when the joint capsule is put on a stretch. On the other hand, permanent folds may be observed These comprise villi projecting into the joint cavity, they may be fine fingerlike projections or clusters of branching villi while others are short and clubbed and project from a broad base

Usually the synovial cells are found in clusters several rows deep, occupying a position on the surface, particularly the surfaces of villi A fine fibrillar stroma separates the cells so that the surface covering is not complete Although they exhibit marked polymorphism most of them are cuboid, spherical or polygonal in shape A Golgi apparatus characteristic of secretory cells has been demonstrated in many of the cells While the office of some synovial cells is to secrete mucin others function as phagocytes these usually are situated in the deeper layers and have an affinity for colloidal particles of certain dyes and particularly matter such as carbon particles of India ink

The synovialis responds promptly to injury or disuse In general, the response is similar to that of all connective tissues, namely by the formation of granulation tissue However, this structure has the power to regenerate so that when destroyed by trauma or disease or when removed surgically, regeneration can be anticipated if the causative factors are eliminated and if the pathologic processes have not progressed to irreversible stages

Synovial Fluid

In general, synovial fluid closely resembles plasma, both from a chemical and a serologic viewpoint. However, its protein and total solids are less than those found in plasma. It is the dialysate of plasma which contains mucin, a product secreted by specific cells in the synovial membrane Synovial fluid appears first as a filtrate from the subsynovial capillary bed, later, mucin is added in the joint cavity, giving the fluid its gross characteristics, the mucoprotein content is responsible for the high viscosity and the lubricating nature of synovial fluid It is a clear, slightly yellow tinged fluid with a pH of 8 2 to 8 4 According to Kling, its viscosity ranges from 10 7 to 20, its total solid content from 4 to 4 4 per cent, and it has a specific gravity of 1.040 The cell content varies but in normal fluid it is usually under 60 cells per cu mm. and rarely exceeds 200 cells per cu. mm The predominant cells are mononuclear 95 per cent of them being mononuclear, while 5 per cent are polymorphonuclear, from 30 to 60 per cent of the mononuclear cells are synovial lining cells (Kling), and the rest are monocytes, macrophages and lymphocytes. Meyer recorded that the viscosity is due, to some extent, to hyaluronic acid Although the viscosity of normal fluid is greater than the pathologic it contains less hyaluronic acid, which in pathologic states may be changed by hyaluronidase The amount of synovial fluid in a joint is small (0 5 to 3.0 cc in the knee joint) nevertheless, it performs specific functions Its two prime functions are (1) to provide adequate lubrication for the articular ends of the bones and (2) to supply nutrients to the articular cartilage. In ad

dition its high alkalinity protects the articular surfaces from noxious acid substances which are by-products of normal metabolism. Normal joint function is essential for the maintenance of an adequate supply of fluid in the joint The rich vascular bed in the subsynovial stratum makes essential nutrients in the plasma readily accessible while the ample lymphatic plexuses in synovial membranes provide an efficient mechanism for the removal of undesirable by-products of metabolism and those produced by disease The phagocytic nature of some synovial cells regulates the interchange of colloids between the synovial fluid and the blood and the lymphatic systems and plays a major role in the reaction of the joint to noxious factors Interference in the normal metabolic interchanges negotiated by the synovial fluid is reflected in the response of the synovial membrane and degenerative changes in the articular cartilage

The composition and the volume of synovial fluid exhibit alterations from the normal early in any form of inflammation of the joint The extent of swelling is governed by the amount of free fluid in the joint cavity and the fluid in the periarticular tissue Concomitant findings are (1) increase in the protein content of the fluid and (2) decrease in the sugar content Increase in the globulin fraction is chiefly responsible for the rise in the protein concentration. With inflammation fibrinogen and prothrombin appear in the synovial fluid These substances cause clotting The mucin content increases and the pH of the fluid shifts to the acid side Increase in the number of cells occurs immediately with any inflammatory process. Acceleration of the inflammatory process is accompanied by turbidity of the fluid The predominating cells found vary depending upon the noxious agent and the duration of the synovitis In acute traumatic synovitis the predominating cells are polymorphonuclear types in chronic synovitis resulting from repeated traumas, the mononuclear cells usually predominate

Mechanical or clinical irritants also initiate a characteristic response in the synovial membrane The special synovial cells are stimulated to increased activity resulting in increase in the mucin content of the fluid and hypertrophy and increase in the number of cells The entire synovialis becomes thickened hyperplastic hyperemic and edematous The lymphatic system is unable to remove harmful products and debris produced by the pathologic process the lymphatic channels become obliterated by increased intra-articular pressure thereby permitting accumulating irritants to stimulate still further the synovial membrane This same process is observed following extensive hemarthrosis here additional irritating agents are produced by decomposition of the red blood cells. In the light of the aforementioned observations it becomes apparent that continued irritation of the synovial membrane no matter what the causative agent may be results in pathologic alterations in the synovialis which are referred to as chronic synovitis. Chronic synovitis may or may not be associated with changes in the cartilaginous and the osseous elements of the joint since the causative agents and the duration of the malady govern the development of these added features

Acute Traumatic Synovitis

This designation is employed to denote a specific clinical manifestation of the synovialis when it is injured it is not a diagnosis. In most instances the causative factors are readily recognized but occasionally they defy all known diagnostic aids. The most common joint traumas initiating this response of the synovial membrane are those incident to the various types of internal derangements essentially the response comprises the formation of varying amounts of synovial effusion Acute traumatic synovitis is a sequel of all types of acute knee injuries It is of great impor

tance to establish the agent responsible for the joint reaction, only then can proper steps be taken to eradicate the etiologic factor Failure to achieve this may predispose the patient to recurrences of traumatic synovitis This sequence of events is observed frequently in knees in which a segment of a torn meniscus is trapped repeatedly between the articular surfaces of the femur and the tibia or when an inefficient quadriceps mechanism fails to stabilize the knee joints and permits giving way or buckling incidents

Following some form of injury to the knee joint, an increase in the volume of synovial fluid ensues This increase in volume is accompanied by hyperactivity of the secretory cells of the synovial membrane, thereby increasing the amount of mucin in the joint fluid. Absence of gross blood indicates that only avascular structures are involved such as the semilunar cartilages or the articular cartilage. If gross blood is demonstrable one must assume the presence of a coexisting lesion of the vascular elements, such as the periphery of the menisci, the cruciate ligaments the synovial membrane and capsule and the osseous components of the joint. The appearance of gross fat droplets in the fluid is suggestive of intra articular fracture

As noted previously, large amounts of synovial fluid increase the intra-articular tension hence mechanically impairing the normal functions of the synovial membrane, particularly its phagocytic and absorptive actions The protein content of the fluid increases and the alkalinity of the fluid is decreased and shifts to the acid side. There is a rapid rise in the cell content the predominating cells being polymorphonuclear in type and the fluid becomes turbid In addition precipitation of fibrin and prothrombin lays the foundation for the formation of granulation tissue If these circumstances persist the accumulated noxious elements in the joint fluid overwhelm completely the synovial membrane, which undergoes hypertrophy, thickening and later fibrosis It becomes apparent that a concerted effort must be made to remove the irritants from the joint cavity so that the synovial membrane can resume its normal activities Only by so doing can one abort the unfavorable sequelae—chronic synovitis and osteoarthritis also the primary etiologic agents must be identified and eliminated

Clinical Features In uncomplicated cases the pertinent clinical manifestations of this disorder are varying degrees of distention of the joint capsule, discomfort and stiffness in the knee joint The symptoms are the result of mechanical distention of the capsule pain is never severe unless a coexisting hemarthrosis exists Blood irritates the synovial lining and produces intense pain After the injury several hours elapse before discernible swelling of the joint is manifest. This feature differentiates the lesion from hemarthrosis in which swelling of the joint is demonstrable within 1 to 2 hours after the injury

When resulting from some form of internal derangement, traumatic synovitis is accompanied by some limitation of motion this may result from actual mechanical blocking of the joint, from muscle spasm or from both. Some increased local temperature is observed, but rarely is there a general systemic reaction. The regional landmarks of the knee are obliterated by the distended capsule most of the swelling is in the suprapatellar region and on each side of the patellar tendon the patella is forced away from the anterior surface of the femoral condyles Tapping with the index finger elicits ballotment of the patella and a click as it strikes the anterior surface of the femur If the synovitis is a concomitant feature of some form of internal derangement, such as a tear of one of the *menisci*, then the clinical features of the derangement are present

Roentgenologic study of uncomplicated cases, particularly those with no intra

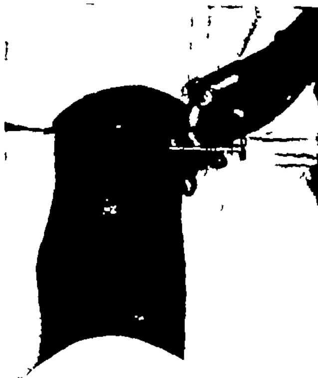


FIG 331 Aspiration of the knee. The procedure should be performed with strict aseptic technic. The preferred site of puncture is on the outer aspect of the knee just above the superior pole of the patella.

articular fracture provides no significant information except a wide joint space in some instances Roentgenograms taken to portray the soft tissues reveal distention of the periarticular tissues Effusion persisting for more than 2 or 3 weeks causes marked stretching of the capsule and the ligaments and relaxation and atrophy of the extensor mechanism Recurrent effusions produce the same results which predispose the patient to development of varying degrees of osteoarthritis and severe dysfunction of the knee joint.

Management. The immediate treatment is designed to reduce intra articular tension and to preserve quadriceps power and control. Later attention is directed toward removal of the primary causative factor such as some form of internal derangement if one is identified

Small effusions with minimal distention of the capsule need not be aspirated A snug elastic compression bandage is applied This enhances absorption of the fluid and restricts joint motion If possible weight bearing should be prohibited for several days However, in some instances complete rest is not desirable by the patient here at least limited weight bearing should be enforced Massive effusion must be aspirated After the joint is decompressed, a compression bandage is applied and bed rest is instituted If the effusion recurs, aspiration is repeated. In all cases progressive exercises of the quadriceps muscle are instituted immediately Only by this means is rapid and disabling atrophy of the quadriceps muscle prevented First, quadriceps drill is commenced this is followed by straight leg raising against elastic resistance later the muscle is made to raise increasing loads. The importance of *restoring the extensor mechanism to normalcy* in these cases cannot be emphasized too strongly Allowing cases of simple acute traumatic synovitis to develop pronounced atrophy and relaxation of the capsule and the ligamentous apparatus indicates that the physician in charge has no knowledge of the role that these structures play in the normal mechanics of the knee joint Many neglected cases develop profound dysfunction resulting from chronic synovitis and eventually osteoarthritis Occasionally, the damage may be irreparable now the only treatment that can be offered is arthrodesis of the joint With adequate treatment the effusion is absorbed in 1 to 3 weeks if the joint is not subjected to more trauma

If the true etiologic factor responsible for acute traumatic synovitis is recognized such as tears of the menisci loose bodies ruptured ligaments or weakness of the extensor mechanism with or without associated lesions, proper treatment to correct the existing disorder should be instituted as soon as circumstances permit Removal of the primary causes will ensure the patient against repeated episodes of synovitis and prevent harmful sequelae

TECHNIC OF ASPIRATION (Fig 331) As-

piration must be performed with strict aseptic precautions After the area is prepared and the knee draped, the site to be punctured is ascertained The preferred site is on the outer aspect of the knee just above the superior pole of the patella Here with a fine hypodermic needle, using 1 per cent procaine, an intradermal wheel is raised, the underlying tissues are then infiltrated down to the capsule. After 2 to 5 minutes a large-bore needle is passed at right angles to the skin, it pierces the vastus lateralis muscle and passes behind the quadriceps to enter the suprapatellar pouch After the joint is evacuated of all accessible fluid an elastic compression bandage is applied

TRAUMATIC HEMARTHROSIS

The amount of free blood in the joint cavity is determined by the severity of the injury and the tissue involved Massive hemarthrosis is the usual sequel to all types of intra-articular fractures such as fractures of the tibial or the femoral condyles, fractures of the patella which are generally associated with rupture of the medial and the lateral patellar retinaculi avulsion of the tibial spine and subchondral fractures of the patella Surgical trauma inflicted on the intra articular structure during some operative procedure may result in postoperative hemarthrosis Swelling of the joint occurs shortly after the above injuries In cases with extensive laceration of the fibrous capsule and the synovialis, much of the blood is dispersed in the periarticular structures consequently, severe distention of the capsule does not occur

Other injuries such as maceration of tabs of the infrapatellar fat pad shredding or rupture of one of the cruciate ligaments usually the anterior ligament laceration of some area of the synovialis or tears in the vascular peripheral attachment of the menisci usually result in small hemorrhages into the joint cavity Often the synovial effusion is only slightly blood tinged Also the blood is not in sufficient quantities to overcome the anticoagulant power of the synovial fluid hence, it remains fluid This differs from the behavior of blood in a massive hemarthrosis Here, as pointed out by Smillie, the anticoagulant property of the synovial fluid is overwhelmed completely, permitting intra articular coagulation. Failure to absorb the clots results in the formation of granulation tissue and ultimately intra capsular adhesions hence, varying degrees of joint dysfunction ensues.

Pronounced intra-articular pressure, such as is produced by large effusions or hemorrhages, obliterates the lymphatic channels which normally remove debris and noxious products from the joint cavity Decomposition of the red blood cells liberates large quantities of hemosiderin which impregnates the synovial membrane All the aforementioned agents are irritants to the synovialis causing hypertrophy, villus formation and fibrosis of the structure

Clinical Manifestations As noted previously, hemarthrosis generally accompanies some form of intra-articular trauma It becomes apparent that it is of the utmost importance to establish early the presence of blood in the cavity of the knee joint Once the diagnosis is established, concerted effort should be made to find the source of bleeding By so doing, an intelligent plan of therapy can be instituted It is essential to remember that hemorrhage is not a concomitant finding of tears of the menisci unless the tears traverse the vascular peripheral attachments On the other hand, ruptures of the cruciate ligaments invariably result in extravasation of blood into the joint cavity

Swelling resulting from active bleeding is demonstrable shortly after the injury occurs This is in contrast with the rate of filling of the joint by traumatic effusion here several hours elapse before the patient becomes aware of the gradual increase in the size of the joint. Pain is an outstanding feature and is accentuated by motion Tenderness is readily elicited by applying firm pressure over the suprapatellar pouch, this maneuver increases intra articular pressure



FIG 332 Tissue obtained from synovectomy in a male 52 years old with chronic villous synovitis. Swelling of the knee had been present 3 years. The entire suprapatellar pouch was obliterated by the hypertrophied and edematous synovialis Observe the loose bodies encountered in the joint. The cartilaginous and osseous elements of the joint were not implicated.

which intensifies the pain Gentle palpation of the periarticular tissues reveals a sense of firm resistance to the examining fingers which is characteristic of tissues distended by blood there is increased local temperature Usually the knee is held in slight flexion both flexion and extension may be restricted in varying degrees The diagnosis is confirmed by aspiration of the joint

Management. From the aforementioned discussion it becomes apparent that the treatment of hemarthrosis is directed primarily toward the lesion responsible for the hemorrhage This is particularly true in *massive hemorrhage associated with fractures* of the patella or subchondral fractures of the patella Grossly blood stained synovial fluid should make one suspicious of a rupture of the anterior cruciate ligament fracture of the tibial spine or tear of the peripheral attachments of the menisci Massive hemarthrosis without severe soft tissue or osseous injury are exceedingly rare but occasionally also occur Regardless of the cause large hematomas of joint must be evacuated in order to relieve intra-articular pressure and to evacuate blood which is an irritant to the synovialis If not removed, blood incites an active inflammatory process After the joint is aspirated in the manner described previously an elastic compression bandage is applied, the leg is elevated, and the knee is surrounded by bags containing ice In cases requiring treatment directed toward the cause of the hemorrhage aspiration is a desirable preliminary procedure.

In the event that no ligamentous or osseous lesions are demonstrable aspiration and compression of the joint may be the only treatment indicated Occasionally, it may be necessary to repeat the aspiration after 1 or 2 days The limb should be at complete rest for 7 to 10 days in order to avoid recurrence of the bleeding Then quadriceps exercises and straight leg raising are commenced this is followed by progressive resistance exercises to restore the extensor apparatus to normalcy

Chronic Nonspecific Villous Synovitis

This designation applies to a group of cases which exhibit pronounced proliferation of the synovialis without involvement of the cartilaginous or the osseous elements of the knee joint The disorder may be observed for many years without simulating the features of rheumatoid arthritis. The etiologic agents are not known this together with the pathologic process being primarily confined to the synovial membrane, makes classification of the entity extremely difficult. The difficulty of classifying the joints affected by this malady was emphasized by Pemberton who suggested a separate classification such as chronic infectious or chronic traumatic arthritis Occasionally the form of synovitis may initiate generalized rheumatoid arthritis Inge records two such cases In some cases the alterations in the synovialis are eventu



FIG. 333 Synovial tissue obtained from case J P a female child 26 months old with chronic villous synovialis Note the numerous rice bodies that were found in the joint cavity many are still attached to the synovialis.



FIG 334 Photomicrograph × 100 of chronic villous synovitis Note the villous formation the round-cell infiltration in the subsynovial strata and the increased fibrosis.

ally complicated by changes typical of osteoarthritis

Generally the lesion is monoarticular however, both knees may be involved The gross and the microscopic features of the synovialis do not differ from those observed in chronic synovitis associated with rheumatoid arthritis osteoarthritis, infectious arthritis or osteochondromatosis Macroscopic study reveals that the synovialis is markedly thickened and often forms numerous folds of varying size It is edematous congested and studded with numerous fringes and villi. Occasionally in cases of long standing one or more loose bodies may be observed these may lie free in one of the joint recesses or may be attached to the synovial membrane (Fig 332) In one case the entire membrane was studded with numerous rice bodies (Fig 333) Microscopically the essential features are pronounced hyperplasia and hypertrophy of the cells comprising the synovial lining so that numerous villi and folds of varying size are formed In addition the subsynovial strata exhibit increased vascularity marked round-cell infiltration and fibrosis (Fig. 334) Pronounced edema of the affected tissues is undoubtedly the result of impairment of the entire lymphatic system of the region As noted previously the rise in intra-articular pressure obliterates mechanically the lymphatic channels whose prime function is to remove noxious products in addition, the phagocytic function of the synovial cells is impaired These alterations permit accumulation of protein substances which reduce the alkalinity of the synovial fluid and allow precipitation of colloid substances including fibrin These agents are irritants to the synovialis This is reflected in hypertrophy and hyperplasia of its cells and marked vascularity and fibrosis in the subsynovial strata

No convincing evidence has been recorded which might point to some organism as the causative agent Bacteriologic studies of the fluid and of the tissues obtained at operation provide no significant information

Clinical Manifestations. Most of the patients are past middle life. The author has encountered three patients under the age of 6 years the youngest was 26 months old The oldest patient encountered was 62

years of age Women are afflicted more frequently than men.

The clinical manifestations are insidious in nature. In the early stages there is some pain and swelling in the affected knee which is accentuated by activity but relieved by rest Some swelling may be more or less constant at all times Later, pain is more severe and the swelling becomes progressively more pronounced Not infrequently pain and tenderness may be worse in the medial aspect of the joint. The patient may be aware of some crepitus in the knee joint on motion.

Physical examination reveals some atrophy of the quadriceps muscle in all cases Varying degrees of swelling are present in advanced cases swelling is discernible below, above and on either side of the patella Occasionally, when the knee is extended a compressible swelling is palpable in the popliteal space This is the result of marked intra-articular pressure which causes distention of the posterior capsule or an accessory pouch in this region Persistent distention of the capsule and the periarticular structures causes some laxity of all the supporting structures of the knee joint particularly the extensor mechanism Walking on rough ground often causes giving way and buckling incidents Such incidents favor progression of the pathologic processes implicating the synovial membrane

Roentgenographic studies fail to provide any significant information they are of value in eliminating specific lesions

Diagnosis. This entity must not be confused with chronic synovitis associated with mechanical disorder or inflammatory processes It has been pointed out repeatedly in this text that any mechanical derangement of the knee joint such as insufficient extensor apparatus relaxation or ruptures of the ligamentous structures, lesions of the menisci or loose bodies may produce chronic synovitis In the early stages this malady may simulate closely nonspecific chronic villous synovitis later the inevitable alterations consistent with osteoarthritis become manifest The true nature of the disorder is revealed when a carefully taken history and physical examination of the knee disclose the basic mechanical derangement responsible for the changes in the synovialis

Inflammatory processes such as rheumatoid arthritis are rarely limited to one articulation moreover the clinical features pertinent to this disorder are readily demonstrable In addition, if the synovitis is the result of systemic or local infection elimination of the focus of origin by antibiotics usually results in a cure Such therapy has no effect on the nonspecific form of synovitis

In some instances of chronic synovitis associated with osteoarthritis the proliferative character of the synovial membrane may resemble the alterations observed in the synovialis of rheumatoid arthritis. These findings have led some authorities to believe that a mixed form of arthritis must exist having the features of both atrophic arthritis and osteoarthritis These cases are difficult to classify

In the event that tuberculous synovitis or neoplastic disease are suspected a punch biopsy of the synovialis will disclose the true nature of the lesion. Serologic examination will exclude cases of syphilitic synovitis

Conservative Treatment. After the diagnosis has been definitely established all cases of nonspecific synovitis should be given a trial of conservative treatment Essentially this comprises restriction of activity to within the tolerance of the affected joint If a large synovial effusion is present aspiration is performed and an elastic compression bandage is applied reduction of body weight in the obese and, most important of all redevelopment of the extensor apparatus to maximum efficiency are encouraged Failure to respond to these measures justifies surgical intervention which is synovectomy

Synovectomy (General Considera

tions) Excision of the synovial membrane has proved to be a satisfactory method of treatment in chronic synovitis not only in the nonspecific forms but also in some cases of osteoarthritis, rheumatoid arthritis and synovial osteochondromatosis According to some workers, Volkmann was the first to perform this surgical procedure, having pi oneered in 1877 in a case of tuberculous synovitis However, Swett and Ellis Jones both in the same year, 1923, laid down the indications and the contraindications for synovectomy in cases of nonspecific synovi tis Also, credit must be given to Gold thwait and John Murphy who reported cases of synovectomy in 1900 and 1916, respectively According to Inge Swett and Jones laid down the following rules which should govern the selection of cases suitable for synovectomy

1 The operation should be restricted to cases of nonspecific arthritis

2 The pathologic processes should im plicate only the synovialis, the cartilagi nous and the osseous elements should not be involved

3 If feasible, all foci of infection should be eradicated

4 Conservative management should be given a trial in all cases

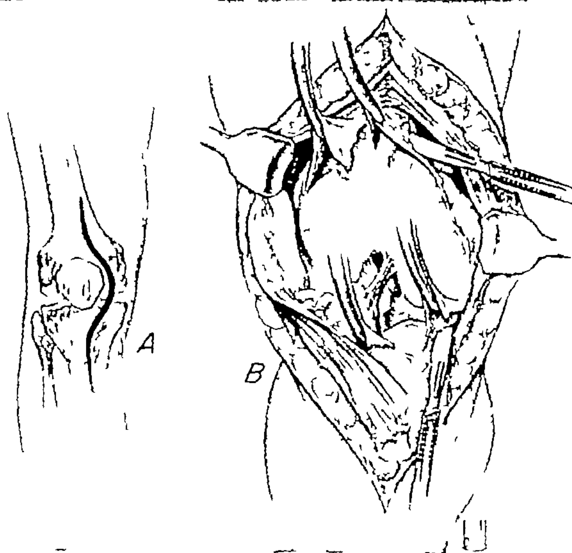


Fig 335 Synovectomy of the knee joint (A) The interior of the joint is exposed through a median parapatellar incision (B) the affected synovialis is removed by sharp dissection

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An exploration of the knee joint was done through a median parapatellar incision Upon incising the bulging synovial membrane hundreds of tiny rice bodies were encountered which packed the entire joint cavity These were evacuated The entire synovialis exhibited a uniform purplish discoloration and was covered with fine villous formations which extended to the margins of the articular cartilage of the condyles of the femur and invested the cruciate ligaments The membrane was studded with numerous rice bodies which were attached to the synovial villi (Fig 333)

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No recurrence of the lesion was found when last examined on January 12 1953, approximately 2 years later the child had a complete range of motion in the knee joint (Fig. 336)

PIGMENTED VILLONODULAR SYNOVITIS

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tients with bilateral involvement in whom a synovectomy was done will request that the procedure be performed on the opposite side.

Discussion of Synovectomy A critical survey of the literature on this topic reveals that synovectomy is indicated in the following disorders affecting the knee joint (1) chronic nonspecific synovitis (2) osteoarthritis (3) traumatic arthritis, (4) atrophic arthritis (5) villonodular synovitis, (6) synovioma and (7) synovial osteochondromatosis Except in derangement of the joint resulting from neoplastic causes a fair trial at conservative management should be the first treatment of choice failure to respond to this method justifies surgical intervention It is generally accepted that the procedure is contraindicated in tuberculous synovitis From a practical viewpoint there are two paramount indications for synovectomy in patients afflicted with the aforementioned disorders (1) pain and (2) removal of pathologic tissue to prevent further disintegration of the joint Age is not a consideration if the patient s general physical condition will tolerate the procedure

The work of Key which was substantiated by Wolcott and also by Efskind reveals that following removal of the synovial lining a new membrane is formed in situ by metaplasia of the underlying connective tissue cells and there is little or no tendency for surface growth from the edges to cover the denuded area He notes that synovial cells are slightly specialized connective tissue cells this specialization being acquired by virtue of their location on a free connective tissue surface From these observations and from the symptomatic and functional improvement in many of these cases it must be assumed that following synovectomy a new synovial lining is formed which approaches the normal As pointed out by Pardee this tissue responds to noxious agents in the same manner as the original synovialis but to a lesser degree since in cases of recurrences the symptoms and synovial hypertrophy are less in intensity than they were prior to synovectomy

In general the best symptomatic and functional results are observed in cases of chronic nonspecific villous synovitis osteochondromatosis, benign neoplastic disease and traumatic arthritis Considerable improvement of function and relief of pain can be anticipated in a relatively high percentage of cases of hypertrophic arthritis (60 to 70%) The poorest results have been reported in cases of atrophic arthritis Nevertheless some workers have observed marked improvement in function relief of pain, and a tendency to arrest the pathologic process where the procedure was performed in some cases of active atrophic arthritis The author s experience with synovectomy in this type of arthritis is too limited to justify comments however in the light of the aforementioned observations further investigation into the possibilities of synovectomy is warranted

It must be remembered that in addition to eradication of the pathologic tissue—and when possible the etiologic factors—the success of the operation is governed in a large measure by the co-operative response on the part of the patient. Failure is inevitable unless a strong extensor mechanism is redeveloped This requires work and patience on the part of the patient and encouragement and guidance on the part of the surgeon The data recorded by Pardee is significant. He noted in a study of 40 cases that regardless of the causative agent including tuberculosis satisfactory results can be expected in 75 to 85 per cent of the cases one year after operation from 10 to 20 per cent will be benefited by synovectomy but the result cannot be rated as satisfactory 5 per cent will be poor results

In this series there were 4 cases of particular clinical interest Two were cases of infectious synovitis associated with osteomyelitis of the patella one in a boy 8 years

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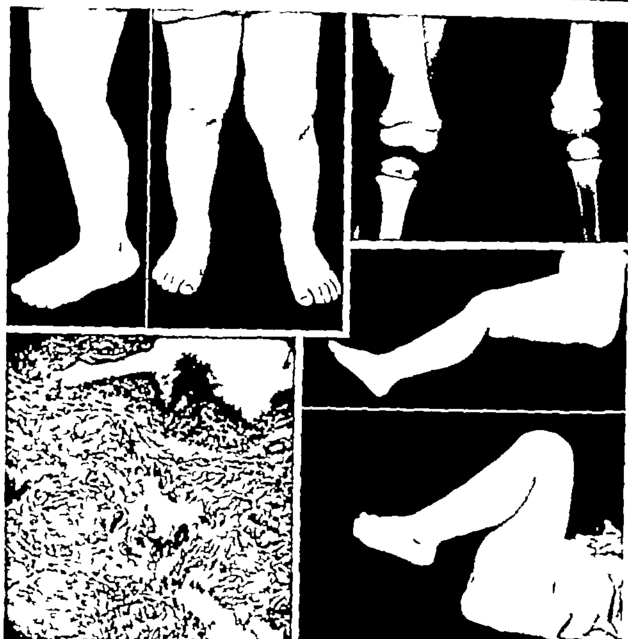


FIG 336 (*Top left*) Swelling of the left knee in a child 26 months old. It appeared 8 weeks prior to the date on which this photograph was taken. Note the diffuse swelling above and below the patella. (*Top right*) Roentgenograms are essentially negative except for distention of the joint capsule (*Bottom left*) Photomicrographs × 200 of the tissue removed from the joint It exhibits a typical pattern of chronic villous synovitis. (*Bottom right*) Range of motion in the affected knee approximately 2 years after synovectomy Note that the swelling has not recurred

resemblance to tumorlike structures particularly the circumscribed or isolated variety many observers believe that it is a true benign neoplasm and it has been described under numerous designations such as xanthoma xanthogranuloma and giant-cell tumor Often the diffuse form is referred to as chronic hemorrhagic villous arthritis or synovitis giant-cell fibrohemangioma fibrohemosiderin sarcoma and benign (or malignant) polymorphocellular tumor of the synovium

In contradiction to the neoplastic theory of origin Jaffe et al are of the opinion that the disease is the result of an inflammatory reaction however they admit that they do

not know what the agent initiating the disorder might be, but they are inclined to believe that it is not bacterial Moreover, they are not of the opinion that local lipoid imbalance or repeated hemorrhage are responsible factors In addition, these workers hold that the so-called xanthomas and giant-cell tumors of tendon sheaths and bursal linings are modifications of the same inflammatory process involving the synovial lining of joints which they have designated as pigmented villonodular synovitis

Another theory of interest was set forth by Geschickter and Copeland They propose that the condition, especially in tendon sheaths, is the result of tumorous proliferation of osteoclasts in sesamoid bones They fail to provide an explanation of these lesions in sheaths of tendons possessing no sesamoid or for the development of the disorder in synovial membranes of joints or in bursae

Other observers maintain that the condition is the result of imbalance of cholesterol metabolism, it may be a local or general imbalance In support of this theory the presence of hypercholesteremia in some cases has been offered, this observation has not been substantiated by the work of other observers A hypercholesteremia was not observed in the cases encountered by the author Jaffe pointed out that the accumulation of lipoid in the form of cholesterol in these lesions does not necessarily point to cholesterol imbalance as the etiologic factor He further noted that it is impossible to reproduce the lesion by intra articular injections of cholesterol or cholesterol ester

This malady has claimed interest for many years Gustav Simon is credited with describing the first case in 1865 He found a tumor in the knee joint of a male aged 64 years whose macroscopic and microscopic features were consistent with the circumscribed form of pigmented villonodular synovitis or according to De Santo and Wilson to an isolated variety of xanthoma In 1894 Turner described a pedunculated tumor in the knee joint, and Dowd in 1912 reported an instance of multiple lesions having histologic features of a xanthoma under the nomenclature 'villous arthritis of the knee' Many other workers have described lesions which fit into the gross and the microscopic patterns of pigmented villonodular synovitis Notably among these are Hartman (1922) Harbitz (1927), Sonntag (1930), Hunter (1931) Kling and Slaskin (1953), Lejars and Rubens-Duval (1910) and more recently De Santo and Wilson (1938) and Jaffe et al (1941)

Pathologic Features. It is interesting to note that pigmented villonodular synovitis implicating the synovial membranes of joints has been encountered only in the joints of the lower extremities, the highest incidence being in the knee joint In the series reported by De Santo and Wilson, the knee was implicated in 36 cases, the ankle in 4, and the scaphocuneiform joint in 1 In Jaffe s series the knee was affected in 18 of 20 cases, Galloway Broders and Gromley observed that the knee was involved in 42 of 48 cases

The observations of Jaffe et al are recorded in the subsequent section These observers describe a diffuse and circumscribed form of pigmented villonodular synovitis

Diffuse Form. The appearance of this variety shows considerable diversity The synovial membrane may be covered entirely with fine villous formation exhibiting a reddish brown color, but in some areas the color may be yellowish brown The villi usually are long delicate prolongations of the synovial lining often tangled and matted together In this form occasionally one or more short stubby villi may be noted whose external configuration is not unlike a nodule Some areas may disclose folds or pads of tissue which comprise villi matted together and flattened, which on section resemble a coarse meshed sponge

Microscopic study of the matted areas reveals that the synovialis is covered by



FIG 337 Pigmented villonodular synovitis—diffuse form. Note the matted and nodular appearance of the synovial membrane The nodules are packed densely and laden heavily with blood pigment. Two free cartilaginous bodies (*left*) were found in the suprapatellar pouch. This tissue was obtained from a male G M aged 53 with a history of 5 years duration of symptoms.

fine delicate villi which are lined by synovial cells and in their stroma numerous fine thin walled blood vessels and hemosiderin are discernible the pigment is also observed in the lining cells of the villi Throughout the loose supporting connective tissue stroma of the villi polyhedral or spindle shaped cells containing blood pigment are interspersed these vary in number Some of the cells bearing pigment appear to have migrated inward from a superficial position others are phagocytic cells formed by the stromal connective tissue Microscopically the more compact matted areas of the synovialis do not differ from the villous areas

The cystologic pattern of the stubby short nodular villi occasionally noted in the predominantly villous variety of the disorder comprise densely packed polyhedral cells which exhibit pigment bearing cells *foam cells* *giant* cells and varying degrees of hyalinization of the stroma. Essentially they disclose the same cystologic configuration of the nodular variety of pigmented villonodular synovitis

The extent of fusion and matting of the villi may give rise to a very complex form of the disease the resulting tissue may obliterate completely the synovial cavity and the suprapatellar pouch Jaffe reported one case which exemplifies this transformation. In a male 18 years of age the first exploration of the affected knee joint revealed uniform villous involvement of the synovial membrane After 2½ years, recurrence of the lesion necessitated further surgical intervention At this time the character of the synovial lining had changed completely, now it appeared as a continuous solid mass of tissue obliterating the suprapatellar and joint cavity it was firm in some areas and spongy in others its color ranged from yellowish to reddish brown and in some areas it was blackish brown Microscopic study of this specimen disclosed that the tissue was the result of hyperplasia of the polyhedral cells and modification of the basic stromal cells The tissues were secondarily impregnated with hemosiderin lipoid or both. Multinuclear giant cells varying in number and size were also demonstrable these were formed by fusion of the polyhedral cells lacking pigment *Proliferation of the polyhedral* cells was reflected in the number of cells showing mitotic figures Foam cells with or without pigment were also encountered

Another form of the diffuse variety is one in which nodular formation is the predominant feature The entire membrane is studded with nodules of varying size and shape generally they are yellowish brown in color and may appear singly or in clus

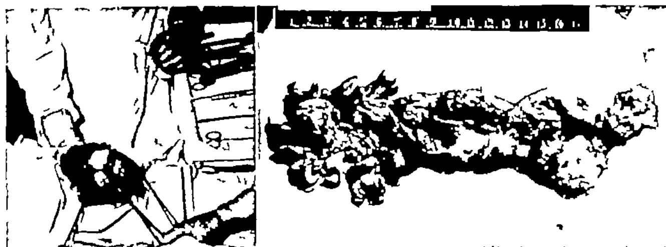


FIG 338 (*Left*) Case R. G aged 23 Appearance of the synovial membrane upon the opening of the joint cavity at the second operation (*Right*) Tissue obtained from the knee joint. Note the grapelike clusters of nodules. The entire synovial lining is implicated both sessile and pedunculated nodules are discernible This patient had a third occurrence 2 years after the second.

ters Also scattered between the nodules, pigmented villous areas are demonstrable (Fig 337) In the author s series there were three cases of this nodular variety Case R. G, a male aged 23 had three recurrences As shown in Figure 338, some of the nodules are sessile in form others are pedunculated It appears that the latter arise from the former, they range in diameter from 0 5 to 2 cm they possess a fleshy elastic texture and a smooth surface Fibrin may be found in varying amounts on the surface synovial membrane Infrequently one or more irregular loose cartilaginous bodies may be present (Fig 337)

Microscopic study of the predominantly nodular form of the lesion reveals that the cytologic pattern is essentially the same as that of the villous variety The nodules comprise densely packed round or polyhedral cells lined by one or more layers of pigmented synovial cells Varying numbers of multinuclear giant cells are present The polyhedral cells contain granules of pigment. Vascularity of the nodules is not as pronounced as in the villous form, and hyalinization in varying degrees is observed in the greater majority of the nodules Variable numbers of foam cells containing granules of pigment are dispersed throughout the nodules. Fusion and intergrowth of the individual nodules or clumps of nodules may result in very complex synovial

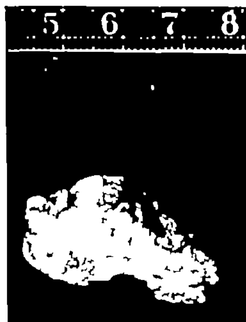


FIG 339 Circumscribed form of villonodular synovitis. This lesion was removed from the inner recess of the knee joint immediately above the medial meniscus. The patient was a male 35 years old the duration of symptoms was 3 years. A localized swelling was palpable on the inner aspect of the knee.



FIG 340 Circumscribed form of villonodular synovitis. The tissue was obtained from the quadriceps pouch of a female, aged 22 Local excision of the mass effected a cure Although the general configuration gives the impression that the mass comprises one large nodule closer scrutiny revealed many nodules matted together and also the presence of small villous areas.



FIG 341 Circumscribed form of villonodular synovitis. A large, fleshy nodular mass found in the suprapatellar pouch of a male 24 years old

structure nevertheless, the basic microscopic pattern is the same in all forms of the lesion (Fig 338)

Circumscribed Form. This is the most common variety encountered It implicates a specific area of the synovialis usually in the region of the medial meniscus or in the suprapatellar pouch The lesion may consist of a single nodule or a large lobulated tissue mass It may be sessile or stalked The nodules and the stalks are yellow or yellowish brown firm elastic and fleshy in consistency Generally the synovial membrane surrounding the lesion is normal occasionally it may reveal areas of villous formation The author has encountered 3 such cases In one the lesion was found on the medial aspect of the joint in a male 35 years of age (Fig 339) the preoperative diagnosis in this case was cystic degeneration of the medial meniscus In the second case the lobulated mass was found in the suprapatellar pouch (Fig 340) in a woman aged 22 years and in the third a male 24 years old, the lesion was in the suprapatellar pouch and was readily palpable (Fig 341)

Microscopically this circumscribed form is similar to the villous and nodular forms Jaffe points out that this variety resembles closely lesions of the tendon sheaths commonly designated xanthomas or giant-cell tumors Essentially the nodule comprises roundish polyhedral cells and is lined by one or more layers of synovial cells some of which contain granules of blood pigment Hyalinization may be demonstrable in the substance of the nodule the cells comprising the structure may contain varying amounts of hemosiderin or lipoid material forming foam cells Foam cells may also contain hemosiderin in addition multinucleated giant cells in varying numbers are present

Clinical Manifestations As noted, lesions involving the synovial lining of joint cavities always have been encountered in the lower extremities By far the most common site is the knee joint, males are affected more frequently than females, in the series reported by De Santo and Wilson, 59 per cent were males, and 41 per cent were females Generally, they occur in the early age groups. The youngest patient in the author's cases was 6 years old Many of these cases parade for a long period under erroneous diagnoses, such as chronic villous arthritis, internal derangement of the knee joint and rheumatoid arthritis Rarely is the diagnosis established before the joint cavity is explored The survey of the literature reveals that the circumscribed variety is encountered more frequently than the diffuse form The interval between the onset of symptoms and the time when medical aid is sought ranges from a few months to 5 years In one series the longest duration of symptoms was 20 years Circumscribed lesions have been observed in older age periods than the diffuse form, Jaffe records such a lesion in a patient 68 years of age

The role that trauma plays in initiating the process is difficult to evaluate Many cases date their symptoms to a specific violence others give vague histories of some form of trauma antedating the clinical manifestations while still others give no history of injury Although violence in one form or another is suggested as a possible etiologic factor there is no conclusive evidence that it is the causative agent.

The cardinal symptoms are pain and swelling that are accentuated by activity and decreased in severity by rest. Usually they are intermittent in nature Generally the pain is mild and is associated with some stiffness of the affected knee joint and at times it is sharp and severe particularly when marked distention of the joint is a concomitant feature Giving way and temporary locking of the joint is not an uncommon manifestation particularly when one or more loose bodies are present in the joint. Pedunculated nodules which are trapped momentarily and crushed between the articular joint surfaces produce the same effect

In the circumscribed variety a tumor mass is occasionally palpable in the supra patellar pouch or on the inner aspect of the knee Also, in the diffuse and nodular form a palpable mass may be demonstrable, especially after aspiration of the joint. Occasionally, the patient is aware of a movable mass which often suggests the erroneous diagnosis of a loose body As a rule, swelling is less pronounced in the circumscribed form than in the diffuse variety, but in both it is intermittent and varies in quantity In the diffuse types swelling resulting from synovial effusion may be pronounced, in fact, the joint may be distended so markedly that severe pain and dysfunction ensue In some the joint fills rapidly with effusion after aspiration, necessitating repeated evacuation of the joint cavity every 3 or 4 days The fluid may be amber colored, serosanguineous or even bloody in character Study of the fluid provides no significant information, some observers have noted a high cholesterol content, others have not The presence of serosanguineous fluid in a knee joint should make one suspicious of some form of pigmented villonodular synovitis

Roentgenographic studies do not give specific information that might establish the diagnosis However, distention of the joint capsule by the effusion and some increased soft tissue density caused by the affected synovial tissue may be demonstrable in the roentgenograms In cases of long standing varying degrees of demineralization of the bony elements of the joint may be evident

Management. Radical surgical excision of the affected synovial membrane is the treatment of choice In the diffuse villous or nodular type a total synovectomy should be performed In the circumscribed variety

the involved tissue, together with a broad base of the surrounding synovial membrane, should be extirpated A partial synovectomy is justifiable when large lobulated tumors are encountered, such as those depicted in Figures 339, 340 and 341 In the diffuse forms it is advisable to remove both menisci and the infrapatellar fat pad and the synovial membrane in the intercondylar notch should be excised meticulously by sharp dissection

Irradiation has been recorded as having effected a cure in some of the recurrent cases This form of therapy as the primary treatment of choice should not be employed because of the severe dysfunction of the knee joint which must ensue

Prognosis. Regardless of the concept of origin of the lesions described in this section be it neoplastic or non neoplastic reactive proliferations most workers are of the opinion that they are benign in nature De Santo and Wilson recorded no instance of malignant transformation in their series of "Xanthomatous Tumors of Joints" and Jaffe et al only warn against the possibility of recurrences in which instances the lesion may be more florid than the original one The author has encountered one case in which there were three recurrences, this patient could not be traced and the true nature of the lesion never was determined However the increasing numbers of synoviomas of joints reported in the literature and the clinical observation that many of these lesions had existed for many months or even years prior to the onset of rapid growth leads one to suspect that some of the malignant tumors are the result of malignant transformations in benign synovial lesions The work of Bennett places strong emphasis on this possibility This observer pointed out that long term follow up studies of so-called benign synovial membrane lesions in which tissue has been removed should be undertaken in order to throw some light on the future course of these lesions having different or varied cytologic and structural patterns Such information may establish histologic criteria" which would distinguish the truly benign from the malignant lesion and serve to identify those lesions which are most likely to undergo malignant transformations This knowledge would govern the future management of all synovial lesions



FIG 342 (A) *Case of pigmented* villonodular synovitus J J, male aged 6 Note swelling of the right knee The demonstrable scar is the result of the *operation performed to obtain a speci*men of synovial tissue for microscopic study

Case Reports (Fig 342) J J, a male 6 years old was first seen in the outpatient department At that time the chief complaint was pain and swelling in the right knee joint. The onset was insidious in nature a specific history of trauma could not be elicited. The first manifestation of the disorder was noted 4 months prior to his first examination There had been a gradual increase in the swelling and the pain the intensity of the pain and



FIG 342 (B) Photomicrograph × 200 Observe the numerous fine pigmented villi and the presence of foam cells.

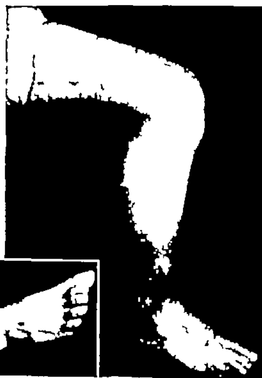


FIG 342 (C) Roentgenograms 1 year after synovectomy Some increased density of the capsular tissues is still present. Also a small spur is formed on the anterior surface of the distal end of the femur

the extent of swelling were increased by activity and relieved by rest.

Examination revealed marked swelling of the joint free fluid was readily demonstrable motion was restricted slightly only in flexion There was some increase in the local temperature of the knee and also moderate para

FIG 342 (D) Range of flexion and extension 1 year after synovectomy No recurrence of swelling or pain has occurred.





patellar tenderness No systemic reaction was discernible He was admitted to the ward service and studied further The temperature range was between 99 5° and 100 F he exhibited a rapid sedimentation rate other wise all other studies including cultures and smears of synovial fluid obtained by aspira tion were negative The synovial fluid was straw colored and slightly turbid cytologic study revealed an excess of mononuclear cells Roentgenographic studies gave no signif icant findings. A biopsy of the synovial mem brane was performed 10 days after admission the microscopic pathologic alterations were consistent with chronic villonodular synovitis no evidence of tuberculosis was demonstrable

A total synovectomy was performed and the infrapatellar fat pad was excised The entire synovialis was found to be thickened hyperemic and covered with fine villi A panus of granulation tissue enveloped the cruciate ligaments and the infrapatellar fat pad The menisci and the articular cartilage of the femur the tibia and the patella appeared to be normal Microscopic studies are depicted in Figure 342 B The final diagnosis was chronic villonodular synovitis

Examination one year after operation (Fig. 342 D) revealed motion at the knee joint from 90° to 180 no evidence of swelling was demonstrable and pain had been relieved completely

R C a male 22 years old struck his right "knee cap while on maneuvers in an Army camp Immediately after the trauma the knee became swollen painful and restricted in motion The knee joint was aspirated three times and a serosanguineous fluid was with drawn at each aspiration. After 4 weeks of rest he was returned to full duty Although he was able to carry on his duties he had intermittent swelling every 3 or 4 weeks he also began to feel a clicking sensation in the knee joint while walking Six months after the initial injury a diagnosis of internal de- rangement of the knee joint" was made The medial semilunar cartilage was removed in September 1942 However his symptoms per sisted and in June 1944 a biopsy of the synovial tissue was done and a benign giant cell tumor was removed through two lateral incisions. Then the patient was discharged from the service On October 15 1945 he was admitted to a U S Naval Hospital his com plaint was severe pain and swelling in the right knee joint

On physical examination there was marked swelling of the affected joint and advanced wasting of the muscles of the thigh The range of motion was from 170 to 110 There was no lateral instability Small firm movable masses were palpable in the suprapatellar pouch The soft tissues about the knee joint were greatly distended. Free fluid was present in the joint and thickening of the synovial tissue was noted

On roentgenographic examination there was considerable decalcification of the femoral condyles and the patella The joint space was wider than normal There was increased density and thickening of the soft tissues about the joint.

Aspiration revealed 250 cc of a dark serosanguineous fluid Cholesterol content of the fluid was not done

Two tentative preoperative diagnoses were made

1 Chronic villous synovitis

2 Recurrent pigmented villonodular syno- vitis of the synovial membrane

The second possible diagnosis was made on the patient's history that a benign giant-cell tumor had been removed in June 1944

Exploration of the joint was performed on October 19 1945 and the joint was opened through a median parapatellar incision. The entire synovialis was found to be markedly thickened and hypertrophied It exhibited a deep-brown rusty color and was studded with polypoid masses varying in size from 2 or 3 mm. to 2 or 3 cm Many of the tumor masses were pedunculated others arose from a broad base of synovial tissue Several grapelike clusters were located in the suprapatellar pouch Between the tumors the synovial membrane lay in deep folds and was thickly covered by numerous villi not unlike the villi found in hypertrophic villous synovitis (Fig 338) The joint was full of a serosanguineous fluid and the products of decomposition of red blood cells were very evident over the entire synovialis and the tumor masses A panus of the above tissue covered the lateral surfaces of the femoral condyles and even ex tended for several millimeters over the edges of the articular cartilage of the condyles and the patella

A complete synovectomy was done The panus extending over the lateral aspects of the femoral condyles and over the articular cartilage was removed meticulously

Postoperatively the patient made an un eventful recovery Six weeks after operation



FIG 343 (*Left*) A case of pigmented villonodular synovitis. F D female, aged 18 years, with swelling of the left knee joint. Her symptoms date back to the age of 5 Observe the atrophy of the quadriceps. (*Center*) Appearance of the synovialis and the articular cartilage of the patella (*left*) and the medial femoral condyles (*right*) Observe the thickened, hemorrhagic synovialis projecting from the suprapatellar pouch above and the intercondylar notch below Marked softening, fibrillation and erosion of the articular cartilage of the patella and the femoral condyles are demonstrable. (*Right*) Tissue removed Note the numerous small bodies that are still attached to the synovialis.

he had a range of motion from 180° to 90° The joint was free of pain at this time. Four months after operation he had gained 20 more of motion. There was only a suggestion of some free fluid in the joint. There was no evidence of recurrence

Pathologic report Gross specimen consists of an elongated irregular band of tissue 16 cm in length. One side is relatively smooth and very fibrous. The other side is markedly irregular and contains numerous polypoid and pedunculated masses up to 3 cm in length. Histologic description The synovial membrane is hyperplastic and exhibits many villous reduplications. In some regions there are xanthoid cells but these are in a minority Inflammatory cells and pigment laden phagocytes are common

This patient was discharged from the service and was not seen again until September 1946 in a civilian hospital At that time the knee was again swollen and painful Motion was possible between 90° and 170° He had constant intense pain palpation disclosed increased local temperature and a firm elastic tumefaction in the knee joint. Aspiration produced 200 cc of dark serosanguineous fluid Roentgenograms showed advanced demineralization of the bone ends and a distended joint capsule.

The patient refused further treatment, and all efforts to trace this patient have failed From the aforementioned findings it is reasonable to conclude that a recurrence of the lesion had occurred

Case F D, female, aged 18 years This case is of unusual interest because of the long duration of symptoms and the unusual pathologic alterations found in the synovialis and the articular cartilage of the left knee joint. The onset dated to when the child was 5 years old the mother noticed some swelling of the knee joint there was no history of injury and no pain The intensity of the swelling varied periodically but never disappeared completely At the age of 6 years the limb was immobilized in plaster for 4 months It has not been possible to determine the reason for this form of treatment, but one can assume that a diagnosis of tuberculosis of the knee joint was the most plausible reason. Following the period of immobilization the patient regained full motion, but the swelling soon recurred Aspiration of the knee was performed at this time and pure blood was obtained. Except for slight swelling, the patient was free of symptoms until the age of 14 years, when the joint became painful and markedly distended, and again blood was obtained on aspiration Recurrent attacks of swelling continued up to the time the author saw the patient

At that time she complained of pain swelling and giving way incidents in the left knee Examination revealed profound atrophy of the quadriceps apparatus when compared with the normal side Motion was unrestricted and no instability of the joint was demonstrable. A definite swelling was discernible in the suprapatellar area The tissues in this region were thickened and had a doughy feel but they were not painful. Some fullness was also noted on either side of the patellar tendon roentgenographic studies were negative All blood studies including cholesterol determination, were within normal limits A clinical diagnosis of chronic villous synovitis associated with quadriceps weakness was made, and exercises designed to develop the quadriceps muscle were prescribed This did not change the course of the clinical picture after 6 weeks the knee became acutely distended and painful on aspiration 40 cc. of fresh blood was obtained A compression bandage was applied and weight bearing was prohibited. After 2 weeks the swelling had subsided considerably but not entirely now protected weight bearing was allowed (Fig. 343) Six weeks after the last episode the joint was explored through a median parapatellar incision

The suprapatellar pouch was distended and thickened when incised bright fresh blood flooded the operative field. Inspection of the entire joint after the patella was displaced laterally disclosed that the suprapatellar *pouch was obliterated completely by numer*ous bulbous hemorrhagic friable villi which bled freely when touched with gauze or instruments. In the infrapatellar region the same type of tissue was encountered (Fig 343) the entire synovialis was implicated in some degree

It was interesting to note the extensive alterations in the cartilage of the patella and the femoral condyles Areas of chondromalacia were observed which were stained varying shades of blue Grossly the discoloration appeared to be the result of penetration of the cartilage with hemosiderin In several areas the entire thickness of the cartilage and even the subchondral bone was infiltrated by the blood pigment (Fig 343)

A total synovectomy and partial chondrectomy were performed The patient made an uneventful recovery and attained within 3 months a range of motion from 180 to 80 It is now 16 months since operation there have been no recurrences however the case is too recent to classify as a cure

Microscopic studies reveal findings consistent with pigmented villonodular synovitis the presence of recent hemorrhages and marked vascularity of the synovial membrane were predominant features No evidence of malignant transformation was detected.

Malignant Synovioma

The designation "synovioma was used first by Lawrence Smith in 1927 other terms commonly employed to identify malignant neoplasms originating in the synovial membrane are synovial sarcomesothelioma, myxosarcoma synovial sarcoma villous angiofibroma and perithelioma. The lesion is observed in regions where synovial tissue is found such as joints tendon sheaths synovial prolongations, recesses or pouches and bursae It is encountered most frequently in the region of the knee joint other common sites in their order of frequency are the foot the ankle and the elbow Although the tumor is relatively rare it is encountered more frequently than is realized The tumor has been observed in all age groups the highest incidence being between 20 and 40 years Bennett observed the lesion in a *child 19 days old It is not generally real*ized that the lesion develops in tissues adjacent to the joint such as synovial pouches recesses tendon sheaths and capsules it rarely arises from the articular synovial membrane

Clinical Manifestations. Pain and swelling are the two cardinal clinical features varying degrees of pain are present in over 50 per cent of the cases (Coley) Swelling is invariably present its duration varies from a few months to several years before a rapid increase in size is noted In the series reported by Bennett the known duration of the lesion ranged from 1 month to 6 years. This latent period suggests the possibility that some so-called benign lesions of the synovial membrane may undergo malignant transformation Although a history of trauma is elicited in some cases

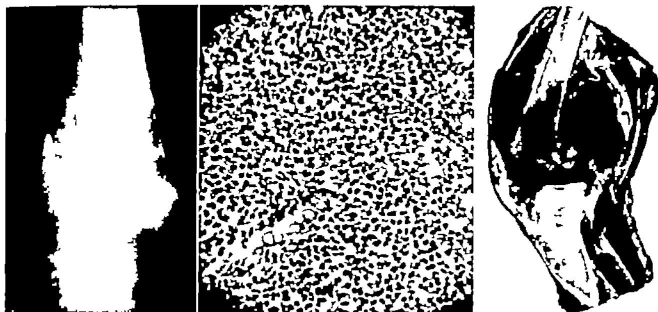


FIG 344 (*Left*) Roentgenogram of a case of malignant synovioma Case G T, aged 44 Observe that the osteolytic process involves the condyles of the femur and the tibia an oblique fracture through the medial condyle of the femur is demonstrable (*Center*) Photomicrograph × 200 Note the cytologic pattern of the lesion which is consistent with malignant synovioma (*Right*) Sagittal section of the amputated specimen reveals invasion and erosion of the lower end of the femur observe the growth of the tumor in the popliteal space and along the anterior surface of the femur The joint space is obliterated completely by the tumor tissue.

there is not sufficient evidence at hand to believe that trauma is the sole responsible etiologic agent. Osseous elements adjacent to synoviomas may be implicated when these structures are invaded the destructive process simulates osteolytic osteogenic sarcoma This process is illustrated in Figure 344 The tumor invaded the entire lower end of the femur the tibial condyles and the patella, so that no normal osseous tissue remained in the affected bone ends It also filled completely the entire joint cavity and ruptured through the upper boundaries of the suprapatellar pouch.

Roentgenographic studies made to depict soft tissue planes and densities may disclose the tumor mass In the event that the adjacent bone is implicated the osteolytic process is readily apparent by irregular destruction of cortical and cancellous bone In case G T roentgenograms revealed marked demineralization of the lower end of the femur and the upper end of the tibia The cortical bone is markedly thinned and the normal bone pattern is lost Lewis pointed out that when by roentgenograms calcareous deposits are found scattered throughout a round or lobulated, sharply defined, soft tissue mass one is justified in making a tentative diagnosis of synovioma He observed this feature in 4 of 10 proved cases of synovioma

The lesion tends to recur after excision to invade adjacent bone and to metastasize to the lungs and the regional lymph nodes Bennett s series discloses the unfavorable outlook in this disease 11 of 32 patients died of metastasis metastatic lesions were present in 2 others and in 3 cases local recurrences of the neoplasm followed excision.

Although it is generally conceded that most cases pursue a protracted course before rapid growth of the tumor is manifest occasionally a case is encountered which begins as a fulminating lesion and disseminates rapidly to other regions This is particularly true if the symptoms are initiated by trauma it may be that the violence is

the inciting agent to a dormant lesion The following case illustrates this point

Case Report. A male aged 44 sustained a twisting injury to the left knee on September 12, 1952, when he jumped off a platform 4 feet high In spite of some pain and swelling he continued to work until October 8 1952 when the knee became greatly swollen and painful He was taken to the local hospital and a diagnosis of a torn meniscus was made On November 9 1952 a lacerated medial meniscus was removed At the time of the operation the surgeon noted a thickened synovial membrane which was reddish brown in color but he failed to remove a piece of tissue for microscopic study Following the operation pain and dysfunction increased progressively in intensity Finally he was confined to bed he was unable to bear weight because the knee would not support him." He was admitted to the Jefferson Medical College Hospital on January 1 1953

On admission the left knee was markedly swollen the overlying skin was tense and shiny the local temperature was elevated. There was abnormal mobility at the knee joint which precipitated intense pain. Roentgenographic studies revealed an osteolytic process involving the lower end of the femur and in addition, a pathologic fracture was demonstrable obliquely through the medial condyle (Fig. 344) Skeletal survey at this time disclosed no metastatic foci discernible by roentgenograms the pulmonary fields were also negative Biopsy of the lesion established the diagnosis. The tumor was a highly malignant synovioma (Fig 344) Two weeks later metastatic foci were found in the lungs and the sacrum This case illustrates that malignant synovioma is capable of pursuing a fulminating course since all took place within a period of 5 months

Macroscopic Appearance. Grossly these tumors are variable in size texture color and configurations Most are nodular masses sharply delineated whose superficial layer comprise densely compressed tissue giving the appearance of a true investing capsule It is not however a true capsule Usually the lesion is attached firmly at several points to a tendon sheath a tendon or some portion of the capsule or the synovial prolongation of a joint In the region of the knee the most common site is the popliteal space Some neoplasms infiltrate the adjacent tissues widely and exhibit no evidence of limiting tissue layers Usually they are vascular lesions When sectioned cystic areas and necrosis of tumor tissue are observed frequently in large tumors The structural texture varies in some the tissue is firm and elastic, indicating abundance of fibrous tissue, while in others it is friable cystic and readily compressible not unlike glandular tissue On section the color of the tumor is extremely variable some are grayish others blue or pink. Throughout the tumor areas of necrosis are indicated by patches of yellowish discoloration and areas of recent hemorrhage are distinguished by their soft reddish brown appearance Occasionally calcareous deposits are observed scattered throughout the lesion Tumors that grow rapidly and invade the surrounding tissues and bone are usually very vascular In the knee joint they fill the entire joint cavity (Fig 344) The affected bone is brittle and crumbles readily under pressure

Microscopic Appearance. The cytologic and structural pattern of this lesion is variable Bennett observed three basic patterns any one of which may predominate They resemble closely the normal structural and functional features of the synovial membrane It was noted previously that the synovialis is endowed with specialized characteristics which control the transportation of certain substances between the articular and the vascular fluids according to some workers it secretes mucin In addition it removes colloids and other particulate substances from the joint fluid Following repeated hemorrhage decomposition products such as hemosiderin and lipoids may overwhelm the function of the synovialis and the ultrasynovial cell since they accumulate in the aforementioned tissues and act as noxious agents Repeated stimulation by these agents may result in marked proliferation of the synovialis which may be laden with large quan

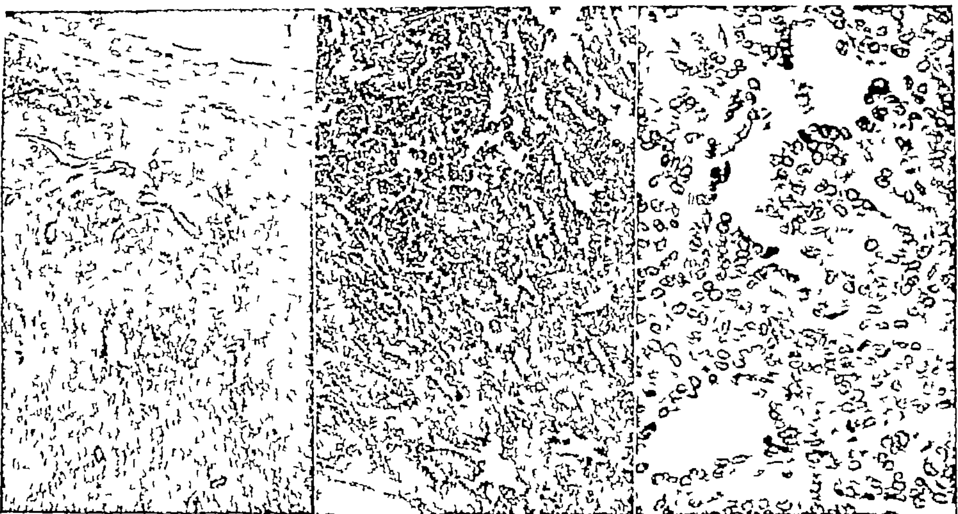


Fig 345 (A) Photomicrographs (*left* × 75 *center* × 60, right × 400) showing a moderately cellular invasive tumor, in which the outstanding characteristic is the formation of clefts and pseudoglandular spaces that are lined by flattened and low cuboidal cells. Small tufts of such cells form small papillary projections into the lumina of the spaces. The resemblance of this lesion to certain benign overgrowths of synovial tissues is apparent. Such similarities are responsible for the difficulties that are frequently encountered in microscopic diagnosis, and point to the need for careful follow up studies in the group of synovial tumors that are believed to be benign This specimen was an egg shaped mass of soft semicystic tissue, which extended somewhat into the tibial cortex just medial to the tibial tubercle (Armed Forces Institute of Pathology Negatives 90603, 90605 90608, Accession number 117723) (Bennett, G A. J Bone & Joint Surg 29 259)



right × 500) of the more solid and simplified type of sarcoma derived
a distinct tendency for tufting and cleft formation are features by
is tumor was seen to be a firm mass the size of a walnut arising in the
of Pathology Negatives 90675 90676 90677 Accession number 80133)

FIG 345 (C) (*Top*, × 60 *Bottom* × 500) The microscopic appearances of a highly characteristic malignant neoplasm of synovial origin. The complex pattern created by the elements supporting the connective tissue and the epithelial like cells that form the tufts and clefts is well illustrated (Armed Forces Institute of Pathology Negatives 90648 and 90649-A Accession number 93364) (Bennett, G A. J Bone & Joint Surg 29 259)

tities of hemosiderin or lipoid material or both. Bennett points out that tumors arising from the synovial membrane exhibit the above features in varying intensities The three basic patterns are (1) the formation of tissue spaces which appear as narrow slits or clefts or spaces not unlike those encountered in glandular tissue also serous or mucinous fluid may be contained in the spaces (Fig 345 A) (2) the formation of cell tufts, appearing as areas of tightly packed oval or polygonal cells or as papillary structures projecting into the tissue spaces (Fig 345 B) and (3) the appearance of epithelial like cells resting on a stroma, comprising elongated cells densely packed with dark staining nuclei (Fig 345 C) This latter pattern is more highly characteristic of the tumor than the other two Silver reticulum stains will invariably disclose reticulum fibers The predominating structural architecture varies in each tumor and one pattern may be clearly discernible while the other two may be identified with great difficulty Likewise mitotic figures are usually demonstrable but their numbers show wide variations Bennett records that it is doubtful whether the frequency of mitotic figures is a reliable index to the degree of malignancy of the tumor Metastatic lesions usually disclose the same cytologic and structural design as the primary lesion.

Diagnosis. Study of the numerous series reported in the literature reveals emphatically that in most cases the diagnosis is not established before a microscopic examination of the tissue is made Because the symptoms are mild and the dysfunction minimal most lesions are considered as benign their true nature is sadly underestimated Failure to understand the tragic implications when such a lesion is encountered results in inadequate treatment The numerous recurrences and development of metastatic lesions to regional lymph and lungs indicates that radical ex of the lesion through a wide base o tissue is seldom achieved Frequen tumor is mistaken for *fibroma*, *xanthoma*, cyst or ganglion It becomes apparent that all tumors or tissue masses resulting from proliferative processes in the region of *joints*, *tendons*, *tendon sheaths*, bursae and synovial prolongations must be *regarded* with suspicion. The possibility of the lesion s being a synovioma must be *foremost* in the surgeon s mind In each case a meticulous microscopic study should be performed to determine the true nature of the lesion Occasionally the symptoms are interpreted as the result of some form of internal derangement, especially if a history of recent injury can be elicited

Biopsy should not be performed in tumors which are movable and readily accessible but instead wide excision of the lesion should be the rule In large diffuse lesions which do not lend themselves to this form of treatment, aspiration biopsy is justifiable in order to establish the correct diagnosis

Treatment The goal in the treatment of all localized soft tissue tumors or tumefactions resulting from reactive proliferative processes should be radical extirpation of the lesion Preliminary biopsy must be condemned when possible, total excision of the mass should be the primary surgical procedure It is reasonable to assume that the many cases of recurrences recorded by numerous workers result from failure to achieve the aforementioned goal Too often the seriousness of the lesion is underestimated and the lesion is not removed in toto Recurrent lesions do not lend themselves to excision now amputation of the affected limb is justified As so often occurs even deletion of the limb does not effect a cure since by the time this mutilating procedure is performed pulmonary metastasis has occurred Local excision is futile in the face of roentgenographic evidence of bone involvemen e the primary treatment of choic amputation Roentgen ra is ineffective be ause the tum lio-resistant Even ter radical s sion of the tumor

the patient should be under close observation for many years It is a known clinical fact that dissemination of the neoplasm may not occur until many years have elapsed after removal of the primary focus

Prognosis. In general, from a long term point of view, the prognosis is poor The *number of cures recorded in the literature* following the removal of malignant synoviomas are few Five year follow up studies do not indicate permanent eradication of the lesion. Cases are on record in which metastatic foci become manifest 5 years or more after removal of the primary lesion. Further investigation of this tumor is most essential such studies should strive to establish histologic criteria distinguishing benign, potentially malignant and obviously malignant lesions in their early stages of development. Such information, as noted by Bennett, may be obtained by long follow up studies of all known synovial lesions regardless of their mode of origin Once obtained, this information may revise the future management of synovial lesions Some observers, even now advocate high amputation or disarticulation of the limb if, after complete extirpation of the tumor histologic study establishes the diagnosis of malignant synovioma. However, the cases treated by primary amputation are too few to draw any conclusions In the series reported by Haagensen and Stout only 4 of 104 collected cases were treated by early amputation These workers also recorded that approximately 25 per cent of the cases with metastasis had regional lymph node involvement while nearly all had metastatic pulmonary foci In the light of this observation the advisability of groin dissection at the time of amputation or excision is indeed questionable

Synovial Osteochondromatosis

This affection implicates the synovial membrane of joints tendon sheaths and bursae It is characterized by the formation of cartilaginous and osteocartilaginous bodies. (See Chap 10 "Loose Bodies")

BURSAE

General Considerations

Bursal cavities are lined with synovial tissue that is similar to the synovial membrane of joint cavities Essentially, the synovial tissue comprises modified connective tissue, having a smooth surface which often is covered by fine prolongations forming villi when it overlies loose areolar or fatty tissue, folds varying in size and number are formed The structural pattern of synovial tissue of bursae, like that lining joint cavities is determined by the nature of the underlying tissue, which may be fibrous, areolar or fatty tissue However, in all three forms the basic cytologic and structural architecture is the same It consists *of surface cells arranged in one or* more parallel layers which overlie a stroma of connective tissue cells and fibers and is richly supplied with vascular and lymphatic channels and nerves Affections which implicate the synovialis of joints may also involve the lining of bursal cavities

The prime function of bursae is to reduce friction between two surfaces when these surfaces are in motion. Hence, numerous bursae are present in the body, particularly in the region of joints Most bursae have a genetic origin however others are formed in response to functional stimuli In general, these structures are encountered between bony structures and a tendon or a group of tendons inserting in adjacent areas of the bone such as the bursa anserina, *between a bony prominence* and a tendon such as the bursa between the tendo achillis and the posterior surface of the os calcis between two muscle masses, such as the subacromial bursa and between the skin and a bony underlying prominence such as the prepatellar bursa Depending upon their location in relation to the body surface, bursae may be divided into two principal groups (1) superficial bursae and (2) deep bursae Bursae situated in the region of joints not infrequently communicate with the joint cavity This is especially



Fig 346 Case of multiple xanthomata Note the implication of the prepatellar bursa.

true of bursae located about the knee joint.

Many agents are capable of initiating pathologic processes in the synovial lining of bursae in general the most common *factors are trauma, occupational strains* infections metabolic disorders and neoplasms Such disorders as villonodular synovitis synovial osteochondromatosis, malignant synovioma and xanthomatous tumors are encountered in bursae (*Fig 346*)

In the region of the knee joint 18 or more bursae have been described (Fig 45) Of these the ones having special clinical significance are (1) the suprapatellar bursa an extension of the joint cavity beneath the quadriceps muscle (2) the popliteal bursae of which the bursa between the medial head of the gastrocnemius and the semimembranosus muscles is the most important (3) the prepatellar bursa occupying a position between the distal half of *the patella and the skin* (4) the infrapatellar bursa situated between the distal segment of the patellar tendon and the anterior surface of the tibia (5) small bursae usually situated beneath the tibial and the fibular collateral ligaments (6) the *superficial pretibial* bursa lying between the anterior surface of the insertion of the patellar tendon and the skin and (7) *the bursa anserina* located on the medial surface of the tibia between the bone and the tendons of the sartorius the gracilis and the semitendinosus muscles and lying superficial to the insertion of the *long fibers* of the tibial collateral ligament The popliteal bursa and the suprapatellar bursa usually communicate with the joint cavity In addition, the following bursa may also communicate with the joint cavity (1) the bursa between the capsule and the inner head of the gastrocnemius muscle (2) the bursa between the capsule and the outer head of the gastrocnemius muscle and (3) the bursa between the tendon of the semimembranosus muscle and the tendon of the inner head of the gastrocnemius *muscle Communication between the tibio*-fibular joint and the knee joint through the popliteal bursa is observed occasionally These avenues of communication between bursal and joint cavities have special clini*cal significance because a pathologic process* originating in one may extend into the other cavity

Forms of Bursitis

Traumatic Bursitis. *Direct trauma to* a bursal sac is followed by distention of the cavity by synovial effusion and occasionally the fluid may be blood tinged Bursae situated on the anterior aspect of the knee joint like the prepatellar and the pretibial bursae are especially vulnerable to trauma Generally single injuries do not result in permanent alterations in the bursal sac.

Repeated minor traumas such as are sustained in certain occupations, *may cause* thickening of the bursal walls and accumulation of fluid The lining membrane shows evidence of degenerative alterations villi and folds are observed frequently also fibrous septa may divide the sac *into com*partments varying in size and numbers In

chronic forms of long duration, rice bodies may form in the synovial cavity, and the accumulated fluid constitutes a bursal hygroma.

Implantation of organisms into a bursal sac may produce a suppurative or non suppurative form of bursitis, depending upon the virulence of the organism. The organisms may be introduced directly into the sac or in the neighboring tissues or they may be brought to the area from a distant focus Suppurative bursitis implicating the prepatellar or the pretibial bursa is a relatively common entity Prior to the advent of the antibiotic agents gonococcal bursitis was observed frequently

Tuberculous bursitis occurs more frequently than is generally realized The most favored sites are the prepatellar, the subacromial and the trochanteric bursae Frequently, the true nature of these lesions is not recognized until the disease has existed a long period of time Incision without extirpation of the entire bursal sac may result in the formation of draining sinuses which may not respond even to extensive antibiotic therapy The author has such a case on hand at this moment

Acute bursitis resulting from invasion of pyogenic organisms is accompanied by rapid swelling and distention of the bursa, increased local temperature pain, limitation of motion and spasm of muscles motorizing the neighboring joint These clinical manifestations are clearly demonstrable when the prepatellar and the pretibial bursae are involved In addition, the acute inflammatory process is accompanied by a general system reaction, comprising elevation of the body temperature, high leukocyte count and increased sedimentation time.

Lesions of tuberculous origin are more insidious in nature and pursue a more protracted course Pain is constant but not as intense as in the suppurative varieties pressure over bursae of both forms elicits tenderness Suppurative bursitis discloses all the local signs of local active inflammatory process

Gouty Bursitis. Implication of bursa may be a concomitant lesion of gouty ar



Fig 347 Roentgenograms of a gouty process in the nonarticular surface of the patella, producing manifestations of an acute bursitis not unlike an infectious process.

thritis Chronic irritation of the synovial lining by chalky deposits in the lumen is followed by pronounced thickening and fibrosis of the bursal walls. Occasionally the process becomes activated suddenly, giving rise to symptoms not unlike infectious bursitis The author has encountered one such case in which the patella was involved in the gouty process The prepatellar bursa suddenly becomes distended and very painful (Fig 347)

Syphilitic Bursitis. Involvement of bursa particularly the prepatellar and the olecranon bursae, have been observed as



Fig 348 Calcification in the prepatellar bursa



Fig 349 Calcification in the infrapatellar bursa

associated lesions of tertiary syphilis Following effusion into the bursal sac, the soft tissues may ulcerate and give rise to draining sinuses The diagnosis is established by recognition of other features of this stage of syphilis and serologic studies the Wassermann test is positive.

Bursitis Associated With Arthritides. Occasionally, chronic thickening of the walls and distention of the popliteal bursa is associated with rheumatoid and osteoarthritis of the knee joint With the knowledge that some of these bursae communicate with the joint cavity, it is reasonable to assume that the pathologic process in the bursa is a direct extension of that involving the articular cavity

Bursitis Associated With Calcification. Calcification in bursal sacs in the region of the knee joint is relatively rare however Brantigen and Voshell noted that calcification beneath the tibial collateral ligament may be responsible for certain cases of Pellegrini-Stieda disease Morley and Bickel reported 8 cases in 1949 which were obtained from the files of the Mayo Clinic The author has encountered one case of calcification in the prepatellar bursa and one of the infrapatellar bursa (Figs 348 and 349) As yet, no satisfactory explanation has been provided for the formation of heterotopic calcification Although trauma must be considered there is no convincing evidence that it is the sole etiologic agent of calcification in bursae. In the aforementioned series 5 patients had a history of injury the remaining 3 did not Microscopic study reveals a chronic inflammatory process involving the synovial membrane and deposition of amorphorous calcium.

Bursitis Associated With Neoplastic and Nonneoplastic Proliferations. It was noted previously that synovial osteochondromatosis villonodular synovitis and xanthomatous tumors may implicate bursae all these lesions have been observed in bursae about the knee joints (Figs 346 to 350)

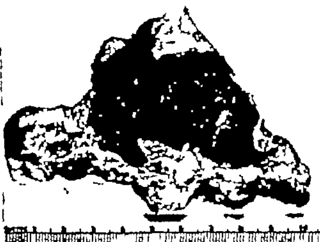


Fig 350 Villonodular synovitis involving the popliteal bursa in a young woman 22 years old.

Management of Bursitis

Acute Traumatic Bursitis. Usually after the initial inflammatory response to single trauma, the effusion subsides gradually, and the bursa returns to normalcy Aspiration, followed by compression bandages and restricted activity, enhances recovery During the early acute stages, cold applications for several days provide considerable comfort later heat applications favor absorption of the fluid Incision or excision of the bursa is not indicated Recently, hydrocortone injected into the cavity is reported to cure a high percentage of cases

Chronic Traumatic Bursitis. If the causative agent is eliminated and the malady fails to respond to simple conservative measures as noted in the treatment of acute traumatic lesions, excision of the bursal sac is justified The author never has looked upon sclerosing agents to obliterate the sac with favor Hydrocortone, 1 or 2 cc., may be tried In several cases the author has observed diminution in the size of the swelling decrease in the thickness of the bursal walls and relief of pain after two or three injections Following excision the walls of the remaining cavity should be kept in apposition by a firm compression bandage until healing has occurred This



FIG 351 Acute prepatellar bursitis.

precaution is necessary to prevent accumulation of fluid between the tissue layers which may lead to the formation of another sac After removal of the sac, the tissues may be approximated by sutures obliterating the remaining cavity The patient must be cautioned against inflicting repeated trauma to the part otherwise an adventitious bursa may form

Suppurative Bursitis. *Essentially* the treatment comprises rest to the knee joint by application of a posterior splint continuous hot fomentations and administration of antibiotic agents Aspiration of the bursal sac and injection of weak antibiotic *solutions (250 units of penicillin per cc.)* into the sac enhances eradication of the suppurative process. If these measures fail, incision and drainage of the sac are justified in addition to systemic administration of antibiotic drugs

Tuberculous Bursitis. In tuberculous involvement of a bursal sac, surgical intervention is the treatment of choice the bursa should be extirpated in toto In addition the use of streptomycin or one of the isonicotinic acid compounds should be employed this tends to reduce the incidence of recurrence of the lesion and prevents formation of draining sinuses

Bursitis Associated With Neopl and Non neoplastic Proliferations. treatment of villonodular synovitis synovial osteochondromatosis of bur similar in every respect to that of the *lesions implicating the knee joint* In eral, it comprises excision of the bursa with its entire contents

Bursitis *Associated With Calci* tion. Excision of the bursal sac is the t ment of choice if the prepatellar or pret bursae are involved *Calcification of l* in the region of the collateral ligam may be treated by needling and inje with hydrocortone failure to respon these conservative measures is an in tion for extirpation of the bursal sac. use of roentgen rays in this disorder is traindicated since it in no way change course of the disease nor does it eradi the symptoms The author has encount several patients with para articular ca cation in which irradiation was used no effect.

Prepatellar Bursitis *This bursa* c lies the lower one half of the patella and proximal one half of the patellar ligam *it is subcutaneous (Fig 351) Chronic* volvement of this structure is encount frequently in individuals whose occupat *require kneeling for long periods* The dition is commonly referred to as "ho maid s knee " All the pathologic proce described previously may involve bursa also the treatment in each insta has been discussed Infectious bursitis i be interpreted erroneously as a suppura process in the knee joint and opening the joint will result in pyogenic arthr When necessary the bursa should drained without entering the joint cav The bursa is opened by two lateral cisions one on each side of the pate After the contents are *evacuated the sa* flushed out with a solution of warm nor saline and packed loosely with a thin st of gauze impregnated with petrolat Postoperative management consists of i

of the limb on a posterior splint continuous hot fomentations and antibiotic therapy Every 2 or 3 days the pack is removed, and a smaller one is inserted until the cavity is obliterated and healing is complete

When the walls of the bursa are thickened markedly it is a simple matter to excise the bursa in toto This is achieved readily through a vertical mid line or a transverse incision 3½ to 4 inches in length. A line of cleavage is developed anteriorly between the skin and the sac and posteriorly between the sac and the anterior surface of the patella and its aponeurosis At the termination of the operation a compression bandage is applied, and the limb is put at complete rest on a posterior splint Hot fomentations are employed until all evidence of inflammation has subsided Generally after 10 to 14 days healing is complete and weight bearing and quadriceps exercises may be commenced

Infrapatellar Bursitis This is a small synovial sac between the upper portion of the anterior surface of the tibia and the patellar ligament the infrapatellar fat pad separates it from the synovial lining of the joint Implication of this structure causes marked limitation of flexion and extension of the joint the soft tissues over the tibial tubercle may become thickened and swelling appears on either side of the patellar tendon It may be the seat of any of the disorders described previously the treatment is also the same

One case of special interest was encountered in which there was widespread calcification of this bursa in fact the process also involved the entire infrapatellar fat pad (Fig 349) A cure was effected by excision of the entire calcareous mass

Anserina Bursitis This bursa is involved less frequently than the prepatellar or infrapatellar bursae As noted previously it is located between the medial aspect of he tibia and the tendinous insertions of he sartorius the gracilis and the semitendinosus muscles It lies anterior to the distal portion of the long fibers of the tibial collateral ligament Adventitious bursae may form in the vicinity of the anserina bursa and even communicate with it Repeated minor trauma may produce an effusion in and thickening of the walls of this bursa Pain and swelling situated in the upper and medial aspect of the tibia should make one suspicious of implication of the anserina bursa Frequently it is mistaken for tissue changes associated with chronic arthritis for meniscal affections ganglions and lesions of the tibial collateral ligament Acute and subacute varieties usually respond to conservative measures such as rest compression bandages and aspiration Surgical excision is justified in cases of recurrence cases resistant to conservative therapy, villonodular synovitis and osteochondromatosis

Popliteal Bursae

Anatomic Considerations The texts on anatomy describe numerous and variable bursae in the popliteal space in relation to the tendons of the hamstring muscles the two heads of the gastrocnemius muscle, the condyles of the femur, the posterior capsule of the knee joint the condyles of the tibia and the collateral ligaments Because some of these bursae are frequently implicated by pathologic processes which require excision of the bursal sacs comprehension of the anatomic location and configuration of these structures is essential. Wilson et al. dissected the popliteal fossae and the medial side of the knee joint of 30 cadavers They noted that the discrepancies recorded in the different texts were the result of "variations in the degree of fusion or lack of fusion between various members of what we may term the six primary bursae" These are (1) the bursa anserina which lies between the tibia and the tibial collateral ligament below and the insertion of the tendons of the sartorius the gracilis and the semitendinosus muscles above

(2) a semimembranosus bursa located between the tibial collateral ligament and the tendon of insertion of the semimembranosus muscle (3) a second semimembranosus bursa situated between the tendon of the semimembranosus and the medial condyle of the tibia, (4) a bursa lying between the medial head of the gastrocnemius muscle and the capsule immediately over the inner condyle of the femur (5) a third semimembranosus bursa, located between the posterior surface of the inner head of the gastrocnemius muscle and the overlying semimembranosus muscle it projects distally and inwardly between the tendon of the semimembranosus and the capsule over the medial condyle and (6) a relatively rare bursa between the tendons of the semimembranosus and the semitendinosus muscles Bursae (2) and (3) frequently communicate and hence are often described as a single bursa

The workers noted that the bursa between the deep surface of the inner head of the gastrocnemius and the capsule over the medial femoral condyle [bursa (4)] and the bursa lying between the superficial surface of the inner head of the gastrocnemius and semimembranosus [bursa (5)] often fuse to form a composite bursa which they have designated gastrocnemio-semimembranosus bursa They encountered this structure in 26 of the 30 dissected specimens in 4 specimens the bursae did not communicate with each other Of the 26 composite bursae 15 communicated with the joint. In the 4 specimens having 2 separate bursae 2 of the bursae under the inner head of the gastrocnemius communicated with the joint cavity On the other hand none of the bursae between the inner head of the gastrocnemius and the semimembranosus had direct extension with articular cavity When a communication with the joint existed it was located in that portion of the composite bursa comprising the bursa under the inner head of the gastrocnemius The opening in the posterior capsule of the joint invariably was observed superior and medial to the oblique popliteal ligament and directly under the most proximal portion of the tendon of origin of the inner head of the gastrocnemius, no stalk or pedicle was observed

The gastrocnemio semimembranosus bursa comprises a superficial and deep portion the former is lax and loosely attached to the adjacent areolar tissue it measures approximately 1 to 1½ inches in length and ¼ inch in width its longitudinal axis parallels the course of the outer border of the semimembranosus, the latter fuses with the tendon of the semimembranosus and the inner head of the gastrocnemius Proximally, the bursa projects around the inner head of the gastrocnemius, covering its superficial surface, distally it extends to the inner tuberosity of the tibia When traced transversely, it was noted that the bursa envelops the adjacent margins of the two muscles and is reflected on the posterior portion of the capsule of the knee joint Frequently septa are encountered in the bursa. The anatomic features of this composite bursa are similar to those of the majority of popliteal cysts observed in this region moreover, the cysts found in children do not differ from an anatomic viewpoint from those observed in the adults

Etiology of Popliteal Cysts. The origin of cystic masses in the popliteal fossa has aroused much interest and is still a controversial topic. Fortunately the derivation of the lesions is only of academic interest it has no bearing on their recognition and management. Adams is credited with the first description of this entity in 1840 believing it to be a distention of bursa under the inner head of the gastrocnemius which communicated with the articular cavity through a valvular opening Gruber in 1885 described the anatomy of distended bursal sacs and posterior herniae of the capsule of the knee joint Since this period numerous workers have studied these cysts supporting one or the other theory of

origin Baker in 1877, recorded a series of 8 cases and another in 1885 He was of the opinion that they were herniae produced by effusion in osteoarthritic knee joints A popliteal cyst is most frequently known as Baker's cyst other names for this entity are semimembranosus bursitis, medial gastrocnemius bursitis and popliteal bursitis More recently, Haggart noted that synovial cysts in the popliteal fossa may be the result of posterior herniae of the capsule of the knee joint or hyperplasia of the normal bursae. Wilson et al take a more positive stand believing that most if not all cysts are the result of accumulation of synovial fluid in the composite gastrocnemio-semimembranosus bursa. In support of their premise these workers point out that (1) the cysts found between the inner head of the gastrocnemius and the semimembranosus muscles occupy a position which corresponds to that of the bursa normally found in this region (2) at operation an intimate attachment is found invariably between the medial and the lateral walls of the deep portion of the cyst and the tendinous portions of the gastrocnemius and the semimembranosus muscles this relationship is also found in the normal bursa found in this interval (3) the location of the point of communication between the cyst and the joint cavity corresponds to that between the bursa and the articular cavity (4) herniations of the capsule can occur only in the presence of increased intra-articular pressure associated with effusions of long standing yet frequently the cysts are encountered in patients particularly children in whom the knee joints are normal in every respect except for the presence of a posterior cystic mass and in which an effusion in the joint never existed. Moreover it is logical to conclude that intra articular pressure is more likely to distend a communicating bursa than to produce a herniation through the posterior capsule

Cause of Effusion in Popliteal Cysts. There is convincing evidence that some form of trauma is the causative agent responsible for the formation of effusions in popliteal cysts. Trauma may be in the form of repeated minor injuries produced by forceful contractions of the adjacent muscles some portion of which blend with the bursal walls, or a single violent contraction which may tear a portion of the wall The presence of hemosiderin in the wall of the bursal sac is evidence in support of this theory Regardless of the form of injury irritation of the bursa is followed by effusion which distends the sac and renders it more vulnerable to repeated injuries incident to joint motion The basis for a chronic inflammatory process is now established, soon the walls become markedly thickened and villous formation metaplasia of connective tissue elements forming cartilage and loculation of the bursal cavity, become manifest Some observers suggest that congenital aberration in the structure of the bursa may initiate the inflammatory process, particularly in children Gradual distention causes pronounced enlargement of the bursal sac. Although the size is variable, some cases have been recorded in which the sac projected as far as mid-calf

Gross Appearance of Hernial Sac. As noted previously the size varies also its walls vary in thickness and its external surface is usually irregular, exhibiting areas covered with fibrous, fatty or areolar tissue The cavity may be loculated showing incomplete fibrous septa Usually the bursa is distended by a viscid yellowish fluid which may be clear or slightly turbid because of the presence of fibrin. As a rule, the lining wall is smooth and glistening occasionally coarse rough areas due to hyaline material are discernible

Microscopic Findings. Generally the bursal lining resembles that of the synovialis in the joint cavity however continued distention of the tissues results in the formation of considerable amounts of highly cellular fibrous tissue which com-

prises the greater portion of the bursal walls This is lined by flattened, modified surface cells comprising connective tissue cells *Generally, the walls are flat but in* certain areas the formation of villi and folds projecting into the lumen of the sac is evident The subsurface stratum exhibits numerous round cells the outer surface consists essentially of fibrous tissue richly supplied by blood vessels Metaplasia of the connective tissue into hyaline and fibrocartilage is demonstrable in certain areas of the bursal wall also, blood pigment may be discernible

Clinical Features. Popliteal cysts are encountered in all age periods The author has observed 7 cases in children under 10 years of age males are affected more frequently than females the incidence in the right and the left knees is approximately the same. The intensity of the symptom is variable in children no pain or dysfunction is noted. The only positive clinical feature is the presence of a cystic, painless mass in the popliteal fossa. In most adults there is some stiffness and discomfort and some have pain of varying intensity which is accentuated by long periods of standing and other activities In some the symptoms are localized to the posterior aspect of the knee in others to the entire knee joint. Generally, the patients are aware of fluctuations in the size of the cyst The length of time that the patients are cognizant of the lesion is also variable it may range from several months to 4 years Usually, the lesion is unilateral but it may be bilateral particularly when associated with arthritis of the knee joint

Physical examination discloses a mass in the posterior aspect of the knee which is not painful over it the skin moves freely on extension of the knee joint the cyst increases in firmness often it becomes very tense On flexion it usually can be displaced from side to side with relative ease It is significant to note that the greater portion of the mass lies distal to the flexion crease of the knee, a feature which was noted both by Haggart and Wilson et al Occasionally, the cystic mass is lax so that it is difficult to distinguish it from the fatty tissue normally found in this region In large firm cysts fluctuation may be demonstrable In some *patients swelling of the* knee joint is a concomitant feature this is particularly true in cases of osteoarthritis. In some cases of this group when swelling of the knee joint becomes more pronounced, the size of the cyst decreases or disappears. Haggart believes this phenomenon is the result of evacuation of the contents of the cyst into the joint cavity On the other hand, in no instance has the author been *able to reduce the size of the popliteal* swelling by compression of the bursal sac. However, it must be admitted that spontaneous interchange of fluid between the joint cavity and the popliteal cyst is possible and must occur in some instance especially when a large patent foramen between the two cavities exists There must be some explanation why this phenomenon does not occur more frequently Some observers *(Wilson et al) suggest that the close prox*imity of the foramen to the femoral condyle creates an obturator in the aperture also the gastrocnemius and the semimembranosus muscles may compress the deeper portion of the sac sufficiently so that the fluid in the remaining portion of the sac is isolated finally the viscid nature of the effusion and the smallness of the aperture may preclude the interchange of fluids.

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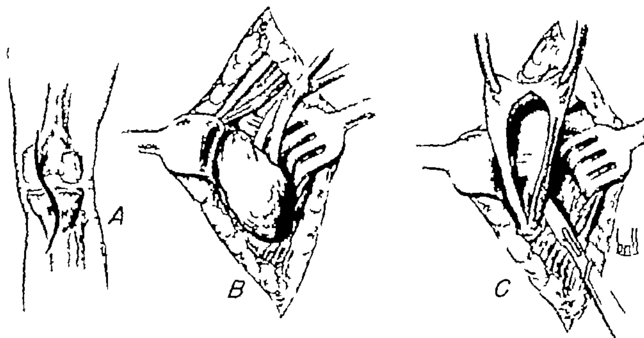


FIG 352 Removal of popliteal cysts (gastrocnemio-semimembranosus bursa) The inner head of the gastrocnemius is retracted laterally, protecting the neurovascular structures from injury (A) An S-shaped incision is made in the posteromedial aspect of the joint, (B) the cyst is mobilized by sharp dissection. (C) Opening of the cyst wall facilitates localization of the aperture between the cyst and the joint cavity

can be demonstrated also by injection of air into the joint cavity

Other diagnostic aids are transillumination of the lesion which may exhibit the cystic nature of the swelling and aspiration of the sac which discloses the viscid fluid characteristic of this lesion

Diagnosis. Small lesions without swelling of the knee joint may be overlooked, and the vague symptoms may induce one to make a diagnosis of some form of internal derangement of the joint Meticulous examination of the posterior aspect of the knee before a diagnosis of internal derangement is made precludes such an error It must be remembered that both lesions may exist in the same knee joint hence care must be taken to elicit the cardinal clinical features of both entities

Bursae besides the composite gastrocnemio-semimembranosus bursa, may give rise to swellings in the popliteal fossa. The semitendinosus bursa lies in the posterolateral region of the fossa, and the semimembranosus bursa in the posteromedial region

Occasionally, aneurysms occur in the popliteal fossa, these must be considered These are pulsating tumors, a bruit may be demonstrable which is synchronous with the pulsations. Hemangiomas are soft tumor masses, often very painful to superficial pressure They exhibit increased local heat and dilated superficial vessels. Roentgenograms may disclose small areas of calcification in the tumor

Varicosities may be responsible for tumefactions in the posterior aspect of the knee. These are recognized readily by the presence of large tortuous soft swellings which are compressible and usually not painful. Other varicosities and at times varicose ulcers are observed in the lower extremity distal to the knee joint

Neoplasms both benign and malignant, may arise in this region. When the diagnosis is in doubt transillumination aspiration and biopsy of the lesion establish the true nature of the lesion Failure to trans-

prises the greater portion of the bursal walls This is lined by flattened modified surface cells comprising connective tissue cells Generally the walls are flat, but in certain areas the formation of villi and folds projecting into the lumen of the sac is evident The subsurface stratum exhibits numerous round cells the outer surface consists essentially of fibrous tissue richly supplied by blood vessels Metaplasia of the connective tissue into hyaline and fibro-cartilage is demonstrable in certain areas of the bursal wall also blood pigment may be discernible

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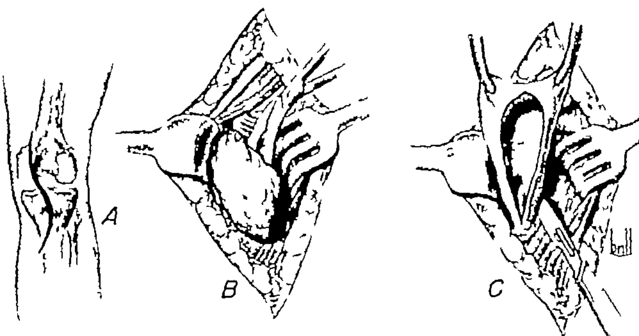


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prises the greater portion of the bursal walls This is lined by flattened, modified surface cells comprising connective-tissue cells Generally, the walls are flat but in certain areas the formation of villi and folds projecting into the lumen of the sac is evident The subsurface stratum exhibits numerous round cells the outer surface consists essentially of fibrous tissue richly supplied by blood vessels Metaplasia of the connective tissue into hyaline and fibrocartilage is demonstrable in certain areas of the bursal wall also, blood pigment may be discernible

Clinical Features. Popliteal cysts are encountered in all age periods. The author has observed 7 cases in children under 10 years of age males are affected more frequently than females the incidence in the right and the left knees is approximately the same The intensity of the symptom is variable in children no pain or dysfunction is noted The only positive clinical feature is the presence of a cystic, painless mass in the popliteal fossa In most adults there is some stiffness and discomfort and some have pain of varying intensity which is accentuated by long periods of standing and other activities In some the symptoms are localized to the posterior aspect of the knee in others to the entire knee joint. Generally the patients are aware of fluctuations in the size of the cyst The length of time that the patients are cognizant of the lesion is also variable It may range from several months to 4 years Usually the lesion is unilateral but it may be bilateral particularly when associated with arthritis of the knee joint

Physical examination discloses a mass in the posterior aspect of the knee which is not painful over it the skin moves freely on extension of the knee joint the cyst increases in firmness often it becomes very tense On flexion it usually can be displaced from side to side with relative ease It is significant to note that the greater portion of the mass lies distal to the flexion crease of the knee, a feature which was noted both by Haggart and Wilson et al Occasionally, the cystic mass is lax so that it is difficult to distinguish it from the fatty tissue normally found in this region. In large firm cysts fluctuation may be demonstrable In some patients swelling of the knee joint is a concomitant feature this is particularly true in cases of osteoarthritis. In some cases of this group when swelling of the knee joint becomes more pronounced the size of the cyst decreases or disappears. Haggart believes this phenomenon is the result of evacuation of the contents of the cyst into the joint cavity On the other hand in no instance has the author been able to reduce the size of the popliteal swelling by compression of the bursal sac. However, it must be admitted that spontaneous interchange of fluid between the joint cavity and the popliteal cyst is possible and must occur in some instance especially when a large patent foramen between the two cavities exists There must be some explanation why this phenomenon does not occur more frequently Some observers (Wilson et al) suggest that the close proximity of the foramen to the femoral condyle creates an obturator in the aperture also, the gastrocnemius and the semimembranosus muscles may compress the deeper portion of the sac sufficiently so that the fluid in the remaining portion of the sac is isolated finally the viscid nature of the effusion and the smallness of the aperture may preclude the interchange of fluids

Roentgenographic study reveals the presence of a globular mass in the popliteal fossa having greater density than the surrounding soft tissues Of course when arthritis of the knee joint is an associated feature, alterations consistent with this lesion are demonstrable Roentgenograms made after aspiration of fluid and injection of air into the sac will reveal in some instances air in the joint cavity and the bursal sac, establishing the presence of a communication between the two cavities This

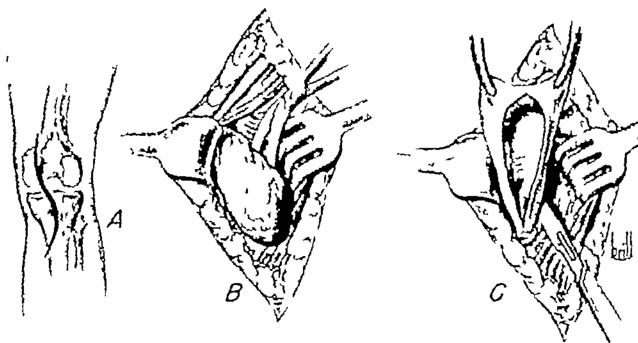


FIG 352 Removal of popliteal cysts (gastrocnemio-semimembranosus bursa) The inner head of the gastrocnemius is retracted laterally, protecting the neurovascular structures from injury (A) An S-shaped incision is made in the posteromedial aspect of the joint, (B) the cyst is mobilized by sharp dissection (C) Opening of the cyst wall facilitates localization of the aperture between the cyst and the joint cavity

can be demonstrated also by injection of air into the joint cavity

Other diagnostic aids are transillumination of the lesion which may exhibit the cystic nature of the swelling and aspiration of the sac which discloses the viscid fluid characteristic of this lesion

Diagnosis. Small lesions without swelling of the knee joint may be overlooked, and the vague symptoms may induce one to make a diagnosis of some form of internal derangement of the joint Meticulous examination of the posterior aspect of the knee before a diagnosis of internal derangement is made precludes such an error It must be remembered that both lesions may exist in the same knee joint hence care must be taken to elicit the cardinal clinical features of both entities

Bursae besides the composite gastrocnemio-semimembranosus bursa, may give rise to swellings in the popliteal fossa. The semitendinosus bursa lies in the posterolateral region of the fossa and the semimembranosus bursa in the posteromedial region

Occasionally, aneurysms occur in the popliteal fossa these must be considered These are pulsating tumors a bruit may be demonstrable which is synchronous with the pulsations. Hemangiomas are soft tumor masses, often very painful to superficial pressure They exhibit increased local heat and dilated superficial vessels Roentgenograms may disclose small areas of calcification in the tumor

Varicosities may be responsible for tumefactions in the posterior aspect of the knee These are recognized readily by the presence of large tortuous soft swellings which are compressible and usually not painful Other varicosities and at times varicose ulcers are observed in the lower extremity distal to the knee joint

Neoplasms, both benign and malignant may arise in this region When the diagnosis is in doubt, transillumination aspiration and biopsy of the lesion establish the true nature of the lesion Failure to trans-

illuminate the mass and to obtain viscid fluid on aspiration points to lesions other than popliteal cysts Occasionally, synovioma and lipoma are encountered in the popliteal space If biopsy is done, it should comprise total excision of the mass Fibrosarcoma generally exhibits a firm texture, it is painful, increases progressively in size and is fixed to the surrounding tissues Transillumination and aspiration are of value only in a negative sense because they eliminate popliteal cysts Biopsy of the tissue establishes the diagnosis Primary involvement of lymph nodes such as Hodgkin s *disease must* be *considered* Usually, there are several nodular firm masses of varying size which are fixed to the deep structures Similar masses may be found in other regions of the body biopsy of the lesion is necessary to make the correct diagnosis

Treatment. Popliteal cysts producing symptoms do not respond to conservative measures the accepted method of treatment is surgical excision If the operative procedure is executed correctly recurrence is rare Involvement of the composite gastrocnemio-semimembranosus bursa and the *semimembranosus bursa, when it exists as a* separate bursa produces a palpable swelling on the medial aspect of the popliteal space usually in the interval between the inner head of the gastrocnemius and the semimembranosus muscles Occasionally a separate semimembranosus bursa may be present on the medial side of the tendon When a separate medial gastrocnemius bursa is implicated the swelling may be present in the mid line of the popliteal space In some instances the bursa may extend beneath the inner head of the gastrocnemius and appear between its inner *border and the semimembranosus* tendon

Excision of Gastrocnemio semimembranosus and Semimembranosus Bursa (Fig 352)

A tourniquet is used in all cases unless contraindicated A lazy S-shaped incision 5 to 6 inches in length and centered over the swelling is made on the medial aspect of the popliteal space The deep fascia is split longitudinally at the completion of this step, the bursal sac comes into view By sharp dissection the superficial portion of the sac is separated from the surrounding loose tissues Traction on the cyst reveals the path it follows between the semimembranosus and the inner head *of the gastroc*nemius muscles The deep portion of the cyst is fused with the tendinous surfaces of these muscles so that a plane of cleavage cannot be developed In order to avoid rupture of the bursal walls a thin layer of the tendinous surface of these structures must be removed together with the sac, by sharp dissection. Dissection continues until the neck or the base of the bursal sac is isolated The neurovascular structures in the middle of the popliteal fossa are protected from injury by the inner head of the gastrocnemius muscle which is retracted laterally In the event that a neck of the cyst is isolated and it is found communicating with the joint cavity it is clamped slightly above its site of attachment to the posterior capsule and then severed The *remaining stump is ligated and inverted by* a purse-string suture In some instances inversion of the stump cannot be achieved In others no closure of any type can be effected The author never has observed unfavorable sequelae following failure to obliterate the opening in the posterior capsule

When no communication is present between the bursa and the joint the base of the sac usually blends intimately with the posterior capsule hence wide excision of the base is essential in order to preclude recurrence of the lesion One should not hesitate to open the bursal sac during the course of its delivery This step facilitates localization of the limits of the sac and finding the aperture between the joint and the bursal cavity

After excision of the lesion the edges of the deep fascia are approximated by inter

rupted cotton sutures, and the subcutaneous layer and the skin are closed in the usual manner Before the tourniquet is removed, the knee is enveloped in several layers of rolled sheet cotton, and compression is made with an elastic bandage

EXCISION OF MEDIAL GASTROCNEMIUS BURSA. As noted above, this lesion is usually present in the mid line An S-shaped incision is made directly over the distended bursa The skin and the subcutaneous tissue are dissected back, exposing the deep fascia, this is divided longitudinally Now the bursal sac usually bulges into the incision The cyst is separated from the adjacent tissues by blunt dissection The dissection is continued until delivery of the cyst is completed, except for its attachment to the posterior capsule of the joint. Flexion of the joint relaxes the posterior structures and facilitates the procedure. After the pedicle is isolated it is clamped, divided and ligated finally it is inverted with a purse string suture. As pointed out by Meyerling and Van Demark in some instances the stump is ligated but not inverted occasionally wide excision of the base of the cyst precludes closure of the capsule which must be left open.

Postoperative Management. Quadriceps exercises are commenced the following day this is followed by straight leg raising and later by elastic resistance exercises On the tenth day weight bearing with crutches is permitted unprotected weight bearing is allowed when the quadriceps show good volume and power usually at the end of 3 or 4 weeks.

INTERMITTENT HYDRARTHROSIS

This disorder is characterized by transitory swelling of a joint recurring at regular intervals The knee joint is almost always implicated although rare the ankle is involved next in the order of frequency The lesion has been described also in joints of the upper extremity but these sites are exceedingly rare Two varieties are recognized (1) the idiopathic and (2) the symptomatic.

The idiopathic type is considered by some as a form of allergic manifestation, and some cases have been recorded in which the lesion has been controlled successfully by desensitization and elimination measures However, these therapeutic measures are not uniformly successful, and the evidence is not conclusive that this is an allergic reaction Schlesinger is of the opinion that the disorder, in some way, is related to angioneurotic edema and points out the similarities in the two maladies Other workers have observed the disorder as a concomitant finding in urticaria asthma and migraine In the light of these observations one must conclude that some neurogenic factor plays a role in the precipitation of this disease

The symptomatic variety is associated with some form of arthritis it is observed more frequently than the idiopathic type. There is clinical evidence at hand to lead one to believe that this form may be an early stage in the development of rheumatoid arthritis Constitutional manifestations, such as anemia and rapid sedimentation rate, are noted frequently Study of the synovialis in these cases discloses varying degrees of proliferation

It is interesting to note the effect of pregnancy Moore observed that the disorder disappeared in one particular case during three pregnancies no swelling occurred from the third month of pregnancy until the third month of lactation. Many reports emphasizing this feature have appeared in the literature. The most significant series was recorded by Bierring, he noted that in 9 cases in which pregnancy occurred 8 of the patients were free of the malady during this period.

CLINICAL FEATURES

Although both men and women are affected it is more prevalent in the latter The lesion may occur in all age periods but it is seen most frequently in the young and

those past middle age the highest incidence is in the third and the fourth decades No case has been reported in the colored races Although intermittent hydrarthrosis has been observed in parent and offspring and in members of the same family, hereditary and familial factors appear to play no role in its causation Often in women it is associated with menstruation trauma may be an initiating factor

Characteristic of the disease are episodes of swelling, coming on suddenly and lasting usually for 4 or 5 days. No associated constitutional reactions are discernible, and no local inflammation of the knee is evident. The only positive finding is diffuse swelling of the joint, producing some discomfort and stiffness The free period between the episodes varies from 5 to 30 days during these intervals the knee joint returns to normalcy, or only minimal alterations are evident The maximum amount of effusion is noted on the second or the third day and then it subsides slowly usually at the end of 4 or 5 days little or no fluid in the knee joint is demonstrable The regular cycles may continue for many years In some there is a tendency for the intervals between the episodes of hydrops to become longer and the intensity of the swelling less In others the free periods shorten, and the joint fails to return to normalcy Many of these patients eventually develop rheumatoid arthritis Occasionally the malady may not manifest itself for several years only to recur with its previous cyclical pattern

Pathologic Alterations

Macroscopically mechanical distention of the capsule and the ligamentous apparatus by large amounts of synovial effusion causes varying degrees of relaxation of their structures The synovialis may be injected and shows evidence of proliferation The synovial fluid has a high specific gravity its cell content is increased from 50 to 60 per cent comprising polymorphonuclear cells, and it invariably exhibits varying amounts of fibrin

Microscopic study of the synovial lining discloses increased vascularity some proliferation and villous formation generalized edema of all the strata of the membrane and cellular infiltration Although some workers have reported the growth of several organisms in cultures of the synovial fluid most evidence fails to support the premise that this lesion is the result of a specific infectious process

Management

Numerous and varied measures have been employed to effect a cure. Aspiration of a large amount of fluid relieves the discomfort and the feeling of tightness in an affected joint but by no means changes the course of the malady Sclerosing fluid of one kind or another has been used without beneficial results These measures should be condemned because they may initiate a chemical synovitis Cases have been reported as cured by nonspecific desensitization typhoid vaccine injected intravenously and foreign protein have been utilized for this purpose However as noted previously desensitizing and elimination measures have not been uniformly successful The allergic manifestations of this disease justify the use of such antihistamine drugs as pyribenzamine and Benadryl for the same reason the value of such agents as cortisone and Hydrocortone should be investigated

In both forms of intermittent hydrarthrosis, synovectomy has been tried and in some cases has effected a cure Two patients in the author's series treated by synovectomy have had no recurrences of hydrops the postoperative period now is 4 years in the first case and 3 years in the second

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12

Arthritides

It is not the purpose of the author to delve in detail into the etiology, the pathogenesis and the pathology of rheumatic diseases such information is readily available in the numerous monographs devoted to this subject. However, for the sake of completeness, a brief discussion of these problems is mandatory Also comprehension of the pathologic processes involved in the varied forms of arthritis is essential in order to interpret correctly the clinical manifestations presented and to formulate an effective plan of management This chapter deals primarily with the chronic forms of arthritis however, since the knee is frequently the seat of suppurative or pyogenic arthritis this disease is discussed also

CLASSIFICATION

Study of the numerous classifications of arthritis encountered in the literature leaves the reader confused and bewildered This stems from the observation that they lack even the most remote semblance of uniformity Some are based on clinical manifestations others on gross pathologic alterations observed in the components of the affected joints others on roentgenographic findings others on the causative agents and still others on a combination of all the aforementioned factors As a result of this disagreement, many unrelated designations have been coined for the different varieties of arthritis, for example hypertrophic arthritis is synonymous with osteoarthritis, hypertrophic and senile arthritis rheumatoid arthritis is synonymous with atrophic, proliferative and focal infectious arthritis The most recent grouping of joint diseases is that proposed by the American Rheumatism Association essentially It is a modification of the classification of Hench

1 Arthritis due to specific infection Specify organism

2 Arthritis due to rheumatic fever

3 Arthritis, rheumatoid Specify as multiple (peripheral) or of the spine (ankylosing)

A. Synonyms of peripheral rheumatoid arthritis atrophic, chronic infectious ankylosing chronic proliferative, arthritis deformans, Still's disease, Chauffard s disease

B Synonyms of rheumatoid arthritis of the spine Strumpell Marie arthritis, von Bechterew's disease, spondylarthritis ankylopoietica

4 Degenerative joint diseases due to unknown cause

A Synonyms osteoarthritis, hypertrophic arthritis arthrosis menopausal arthritis, arthritis of the aged, malum coxae senilis, Heberden s nodes

B Synonyms of degenerative arthritis of the spine spondylarthrosis, hypertrophic arthritis

5 Arthritis due to direct trauma

6. Arthritis due to gout

7 Neurogenic arthropathy (Charcot joint)

8 New growths of joints

9 Periarticular fibrositis

10 Diseases frequently associated with arthritis, arthropathy or arthralgia

A Acromegaly
B Allergy
  a. Intermittent hydrarthrosis
  b Serum sickness
C Cyst of meniscus of knee
D Dermatomyositis
E Disseminated lupus erythematosus
F Drug intoxication
G Erythema multiforme exudativum
H Erythema nodosum
I Hemophilia
J Hysteria
K Ochronosis
L. Osteochondritis dissecans
M Osteochondromatosis
N *Periarteritis nodosa*
O Psoriasis
P Pulmonary osteoarthropathy
Q Purpura, various types
R Raynaud s disease
S Reiter s disease
T Scleroderma

11 Congenital arthropathies

RHEUMATOID ARTHRITIS

Rheumatoid arthritis is a distinct clinical entity characterized by a proliferative process implicating primarily the synovial membrane and the endosteum of the subchondral bone The granulation tissue produced by the synovialis forms a panus over the articular cartilage as it grows from the periphery it is highly destructive eroding and destroying cartilage as it comes in contact with it The *numerous designations* that are synonymous with rheumatoid arthritis are listed in the classifications recorded herein. Inasmuch as the causative agents responsible for this disease are not known the nomenclature must be based on the pertinent and distinctive features of the malady as noted by clinical microscopic and roentgenographic investigations

Clinical Types

Numerous varieties of this disorder have been described in all however the joint pathology is essentially the same From a clinical viewpoint two types *are encountered* The first is ushered in suddenly with severe systemic reactions not unlike rheumatic fever Many joints are affected simultaneously the clinical course is relatively rapid and fulminating *resulting in fibrous* ankylosis of the involved articulations The second type also implicates multiple joints however, its onset is insidious with mild constitutional manifestations Periods of *remissions and renewed activity* are characteristic of this form of the disease with each reactivation the disease process usually is manifest in joints not affected previously Pronounced and progressive dys*function in all affected* joints ensues this is accompanied by advanced muscle atrophy and flexion deformities In both varieties the disease eventually becomes extinguished often leaving in its wake a mass of humanity hideously distorted decrepit and completely helpless (Fig 355) No other affliction ravishes the human body and mind to a greater degree When the joints are immobilized, either by fibrous or bony ankylosis they are no longer painful however, ankylosis often occurs with *the joint in a position which precludes* useful function of the limb

Rheumatoid arthritis may occur in childhood Still was the first to describe it hence it is referred to as Still s disease In spite *of the fact that this malady in every respect* resembles closely the form observed in adults some workers regard it as a separate and distinct entity This belief is not supported by the gross and the microscopic pathology *of the affected joints which re*veals that the pathologic alterations observed in children and adults are essentially the same

The relation of rheumatic fever to rheumatoid *arthritis is a very controversial sub*ject Some observers regard rheumatic fever rheumatoid arthritis and degenerative arthritis as different body manifestations initiated by the same etiologic factors as infection trauma allergy *and cold* The

different expressions are supposed to be governed in a measure by the age, sex diet and environment of the individual From a clinical viewpoint the pertinent difference between the two disorders is the presence of cardiac involvement, which is a constant concomitant finding in rheumatic fever Cardiac lesions are rarely encountered in rheumatoid arthritis The presence of subcutaneous nodules is not a distinguishing feature, although they are more numerous and observed more frequently in rheumatic fever, they are also associated lesions in rheumatoid arthritis

Etiology

Numerous and divergent fields have been investigated and are still being studied in attempts to unravel the enigma of the etiologic factor or factors responsible for rheumatoid arthritis As products of these intensive investigations many theories of causation have evolved Unfortunately, as yet the true cause has not been discovered but it is safe to state that the results of some of the research are promising and hopeful particularly those dealing with the role of the pituitary hormones and the adrenal cortex

Infectious Theory The clinical manifestations of rheumatoid arthritis suggest that infection in some manner plays an important role in the inflammatory process nevertheless conclusive evidence acceptable to all workers has not been provided nor has the infectious agent been agreed upon Up to the present time this premise has been looked upon with favor by numerous workers. Cecil Nicholls and Stainsby found streptococci in the blood and the joints of patients afflicted with rheumatoid arthritis Organisms believed to be responsible for the disorder were isolated from lymph nodes and synovial fluid by Rosenow Loeb, Quigley and Moon also by Burbank and Hadjopoulos On the other hand other workers have failed to recover bacteria from blood, synovial fluid or the synovial membrane Filterable viruses have also been incriminated as possible causative agents Critical assessment of the many reports in the literature leads one to conclude that the evidence in support of the infectious theory is unsatisfactory and inconclusive According to this hypothesis implications of the joints in rheumatoid arthritis is achieved by one or a combination of the following methods (1) direct invasion of the joint by bacteria via the blood stream, (2) response of the joint tissues to blood borne toxins which are released from distant foci of infection and (3) the joint reactions are manifestations in response to bacterial allergy The last mode of causation was supported enthusiastically by Hans Zinsser

The presence of antibodies and hypersensitization of the patient as disclosed by skin tests are evidences in favor of the infectious theory A high percentage of cases of rheumatoid arthritis exhibit agglutinins in the serum to various strains of streptococci, particularly the hemolytic streptococci, this observation is noted frequently enough to be significant Traut showed that arthritic patients give reactions to intradermal injections of streptococcal filtrates more frequently and with greater intensity than do controls. Serum of patients with this disorder shows an increase in the streptococcal precipitins It may be that serums of afflicted patients are endowed with the power to magnify the action of precipitins normally present.

Endocrine Theory Recently, hypersensitization as the cause of rheumatoid arthritis is looked upon with favor by many observers what part the hypophysis and the adrenal cortex play is still speculative, but evidence is accumulating in support of the hypothesis that a close relation exists between hypersensitization and the aforementioned glands of internal secretions

Selye records that allergic manifestations are expressions of the *general adaptation* syndrome (alarm reaction) which is the

body response to noxious influences The anterior pituitary and the adrenal cortex are involved primarily the anterior lobe of the hypophysis produces a corticotrophic hormone which induces the adrenal cortex to produce and deliver corticosteroids According to Rachemann, from a viewpoint of allergy, sensitized patients react differently some are conditioned to develop allergic manifestations in the form of asthma and others rheumatic disorders.

Rheumatoid arthritis developing in women past middle life and incident to the period of the menopause has been considered by many to be the result of endocrine imbalance The evidence in support of this theory is not acceptable

Metabolic Theory According to some authorities rheumatoid arthritis is the result of the inability to utilize carbohydrates adequately Pemberton was an ardent supporter of this hypothesis. He showed that patients with rheumatoid arthritis exhibited a lowered glucose tolerance and he believed that the disorder at least in part was the result of the ingestion of highly concentrated carbohydrate foods. The aforementioned worker also noted that an alimentary hyperglycemia was invariably demonstrable in patients afflicted with *rheumatoid arthritis A lowered sulfur content* has been incriminated as playing a part in the precipitation of rheumatoid arthritis However the above premises have not been substantiated with convincing evidence and hence have not been accepted

Deficiencies in vitamins and various minerals have been considered as possible causative agents of this disorder practically all the known vitamins have been indicted at one time or another This has led to the indiscriminate use of large dosages of vitamins singly or in combination this practice has accomplished nothing except to increase the financial burdens of many whose disability has already depleted their economic resources It is common knowledge that an adequate and well balanced diet provides all the essential vitamins

Circulatory Disturbances. Circulatory deficiencies may be contributory factors in the development of pathologic abnormalities in joints of patients with rheumatoid arthritis. De Takats is of the opinion that rheumatoid arthritis is comparable with Sudeck s bone atrophy, since in both lesion abnormal vasomotor reflexes are present and responsible for the pathologic changes It is common knowledge that many sufferers of this disorder exhibit inferior general circulation characterized by a vasomotor disturbance of the spastic variety this is particularly true in women. The resulting circulatory alterations are demonstrable in the peripheral circulation of the extremities the hands and the feet are cold damp and have a bluish tint Impairment of the local circulation may be responsible for some of the joint changes It has been demonstrated that the capillary bed of affected joints is partially occluded The mechanism of this phenomenon is not clear It may be the result of spasm of the arterioles, arteriosclerosis or mechanical obliteration of the lumen of the vessels by emboli or thrombi One must remember however that the circulatory abnormalities are not totally responsible for the pathologic changes in the joint since they are peculiar *to the specific type of individuals prone* to develop the disease and are often demonstrable before the onset of joint manifestations

Neurogenic Disturbances. Many patients with rheumatoid arthritis exhibit clinical features which are linked closely to the central and the sympathetic nervous systems Although it has not been possible to indict abnormalities of these systems as the etiologic factors it is reasonable to assume that they play some part in the pathologic alterations in the joints Nervous instability and apprehension are observed frequently mental stress and hardships are known to antedate the onset of the disease in many patients. As recorded previously de Takats believes that abnormal nutritional reflex initiated by a chronic

inflammation such as that observed in a joint of rheumatoid arthritis is the result of vasomotor and reflex disturbances, and in this respect the disease is similar to Sudeck's bone atrophy On this basis the capsular and the periarticular swelling in rheumatoid arthritis is due in part to efferent vasodilator stimuli which are conducted by the parasympathetic fibers located in the posterior roots to the spinal cord This reflex mechanism induces an active inflammation which in turn is followed by hyperemia of adjacent bone and osteoporosis, a finding characteristic of rheumatoid arthritis

Predisposing Factors. There is sufficient clinical evidence to justify the belief that certain factors tend to precipitate the disease Notably among these are endocrine, metabolic and circulatory disturbances also prolonged mental stress and physical exertion, debilitating diseases, infectious diseases, focal infections, exposures to cold and inclement weather and malnutrition—all are factors which may initiate the malady Rheumatoid arthritis is not a hereditary disease however evidence is accumulating that the constitutional tendency is inherited As pointed out by Traut, the hypersusceptibility of the mesenchymal tissue is characteristic of this type Vasomotor instability which may be a manifestation of endocrine dysfunction is a constant concomitant feature

Clinical Features

Age, Sex. The disease is encountered most frequently between 20 and 40 years however it may occur occasionally in the fifth and the sixth decades and in children Rheumatoid arthritis in children is known as Still's disease. This is a distinguishing feature between rheumatoid and degenerative arthritis the latter usually develops after middle life. Women are afflicted more commonly than men, some series report ratios of two to one others of three to one.

Joints Involved Most Frequently The joints of the hands and the feet are implicated most frequently next in the order of frequency are wrists, ankles, elbows, knees, hips, shoulders, spine and temporomandibular joints In the greater majority of cases the disease is a polyarticular arthritis, in rare instances it is monoarticular In cases of multiple joint involvement the joints of *the hands and the feet are affected first* then the wrists and the ankles and finally the elbows and the knees In some cases all joints are affected, including the spine and the temporomandibular joints



Fig. 353 Rheumatoid arthritis of both knee joints in a male 36 years old. Observe the external capsular thickening, distention of the capsule and atrophy of the thigh muscles a 20° fixed flexion contracture exists in each knee.

Physical Signs. Generally the patient presents a body type readily recognized, there are exceptions to this rule The patient is thin, malnourished, pale and apprehensive These patients complain of constant fatigue which is intensified by any form of exertion. Poor muscle tone, low blood pressure, vasomotor instability, secondary anemia and lowered metabolic rate are other concomitant features The affected joints are swollen, usually fusiform in shape, and tender All motion is painful and guarded muscle atrophy is an outstanding manifestation The profound muscle atrophy proximal and distal to the pathologic articulation is responsible in a large measure for the spindle-shaped ap-

pearance of the joint The skin over the joint is drawn tightly and is shiny local temperature is invariably increased Palpation reveals a characteristic doughy feel of the periarticular structures this is the result of thickening of and edema in the capsular and the pericapsular tissues (Fig 353) In most instances pain tenderness and limitation of motion are governed by the severity of the inflammatory process however, occasionally all the earmarks of rheumatoid arthritis are present except pain The aforementioned physical signs are not pathognomonic of rheumatoid arthritis since they are manifest in all forms of acute and chronic diseases of joints More diagnostic of the disease is the marked tendency toward flexion contractures of the affected joints In the early stages of the disease the deformity is the result in a large measure of muscle spasm later shortening of tendons ligaments and muscles and formation of adhesions and structural changes in the bony elements of the joint supervene all of which permanently fix the joint in the position of flexion

Pain may be intermittent or constant however its intensity is accentuated with each bout of increased activity of the inflammatory process Immobilization of the joints invariably is followed by relief of pain suggesting that the strain of capsular tissues ligaments and muscle attachments may be the prime factor causing pain

Inclement weather definitely affects patients with rheumatoid arthritis Exposures tend to accentuate the arthritic symptoms It appears that changes in the barometric pressure are reflected in blood pressure and peripheral circulation of these patients According to Pemberton sudden changes in the weather cause exacerbations of the symptoms because the vasomotor circulatory apparatus fails to make the adaptations necessary to meet the abrupt changes in the environment

Course of the Disease

Rheumatoid arthritis may be ushered in by one of many ways Not infrequently the first symptoms are constitutional in nature the patient tires easily the appetite is poor, the hands and the feet are cold and clammy, he loses weight and exhibits a pallor These manifestations may antedate joint symptoms by many months On the other hand the patient may have one episode of the disease or exacerbations may occur after months or even years The disease may assume a subacute or chronic course with periods of exacerbations and forges forward in this fashion implicating and destroying numerous joints until the patient is a helpless invalid

The constitutional manifestations in most instances are the predominant clinical features as noted previously, they may precede the joint symptoms Usually the onset is insidious the symptoms often being intermittent in character In addition to fatigue loss of weight and appetite temperature elevations between 97.5° and 101° F are observed night sweats may occur confusing the disease with tuberculosis Stiffness numbness and tingling in the fingers and the toes may be the first local manifestations particularly in women In a small percentage of the cases (according to Traut 10%) the disease announces itself with abruptness resembling rheumatic fever

In most cases the small joints of the hands and the feet are implicated first usually the proximal interphalangeal joints these become swollen and assume a spindle shaped configuration Later the metacarpophalangeal joints are involved A characteristic feature of the disease is the symmetrical involvement of the peripheral joints In a small group of cases the disease is monoarticular Once a joint is affected it produces symptoms of varying intensities which are accentuated periodically As noted previously the intensity of the pain varies it may be initiated only when the joint is moved actively or passively In other cases it is a prominent feature In the polyarthritic variety frequently the wrists

are involved It is interesting to note the alterations that occur in the nails of these patients, the nails are often ridged longitudinally, pitted and lose their normal luster the nail beds are invariably cynotic. Concomitant alterations are also noted in the muscles the tendons and the ligaments of the affected limb The muscles exhibit rapid and profound atrophy the muscles the tendons and the ligaments are sensitive, when firm pressure is made, marked tenderness is elicited In spite of the advanced atrophy and loss of tone, the muscles are usually hyperexcitable It is interesting to note that in cases with far advanced multiple deformities, pain may be minimal Synovial fluid obtained from affected joints is slightly turbid its specific gravity and protein content are elevated the polymorphonuclear cells are increased and predominant, especially during exacerbations of the local inflammatory process, the sugar content is decreased From 10 to 20 per cent of patients with rheumatoid arthritis exhibit subcutaneous nodules, particularly along the ulnar surface of the forearms usually they are symmetrical and multiple and develop at the sites of previous trauma The size of the nodules varies they are firm not tender and may be freely movable or fixed to the underlying tissues but firmly attached to the skin Their duration is also changeable varying from weeks to years.

Relapse of the Disease

Relapses may occur after months or years of inactivity Specific factors have a tendency to precipitate the relapse such as fatigue, mental stress and exposures to inclement weather fatigue is considered by far the most important single agent The types and the quantities of food ingested are believed by some to bear a certain relation to the occurrence of relapses This is however questionable it appears that an allergic phenomenon initiated by specific foods is a more probable factor Depletion of the body economy by metabolic diseases repeated respiratory infection and trauma in some instances may be responsible for reactivation of the disease It is interesting to note that some hormonal influence during pregnancy tends to improve the general condition of the patient and causes the acute local manifestations to subside. On the other hand, symptoms are often accentuated during the menstrual cycle

Reactivation is favored by body inactivity which is responsible in a large measure for loss of muscle volume, poor circulation of blood and lymph and formation of adhesions Activity is the keynote in avoiding the aforementioned sequelae it should be enforced on the patient and executed always within the patient's tolerance of pain and endurance Much can be achieved in restoring general health and preventing relapses by simple measures such as a well balanced diet, periods of mental and body relaxation and moderate activity

Blood Studies

In most cases the sedimentation rate is elevated markedly and it becomes more so during periods of exacerbations It is a valuable index in determining the degree of activity of the disease However, in rare instances low sedimentation rates are observed in patients whose other clinical manifestations indicate active inflammatory processes, in others, elevated readings are obtained when from a clinical viewpoint the disease is inactive. This feature is in contrast with readings noted in osteoarthritis, which are of lower values, rarely exceeding 30 mm. Secondary anemia is a concomitant finding of rheumatoid arthritis. The polymorphonuclear leukocyte count is usually elevated and hemograms reveal a shift to the left.

Hypoproteinemia is a frequently associated observation with an increase in the globulin and a decrease in the albumin In well-established active cases of the disease the colloidal gold test may be positive Some workers believe that a persistent positive test is indicative of a poor prognosis

ROENTGENOGRAPHIC FEATURES

In the early stages of the disease the roentgenograms depict no diagnostic characteristics The only findings may be some evidence of increased intra-articular fluid as evidenced by distention of the capsule and some increased thickness of the periarticular tissues With progression of joint change roentgenograms exhibit a narrow joint space and eroded punched-out areas along the opposing articular margins subluxation or dislocation may be demonstrable (Figs 354 and 355) Diffuse demineralization



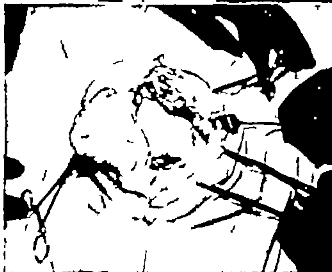




FIG 354 (*Top*) Rheumatoid arthritis of the right knee joint. Observe the narr joint space and the spotty demineralization of the distal end of the femur and t proximal end of the tibia. This joint exhibited a flexion contracture of 20 and a external rotation deformity of the lower leg Compare with the noninvolved left kn joint. (*Bottom left*) Appearance of the right knee upon exposure of the joint Not hyperplastic and thickened synovial membrane this is even more apparent in t specimen removed (*Bottom right*) Tissue removed from the joint depicted h Note the pronounced thickening and the hyperplasia of the synovialis

of the bony trabeculae is a characteristic finding Osteoporosis is the result of two factors (1) hyperemia incident to the inflammatory process present and (2) disuse. Severe loss of mineral salts may render the bony trabeculae invisible in the roentgenograms It appears as though the osseous tissue had melted away, producing the homogenous ground-glass appearance The well-defined articular cortex found in normal joints is not discernible in cases of severe rheumatoid arthritis loss of definition of the cortex is an early feature This results from the destructive and absorptive action of the granulation tissue above and below the articular surface which rapidly thins and destroys the cartilage Marginal erosions are also observed frequently Cases

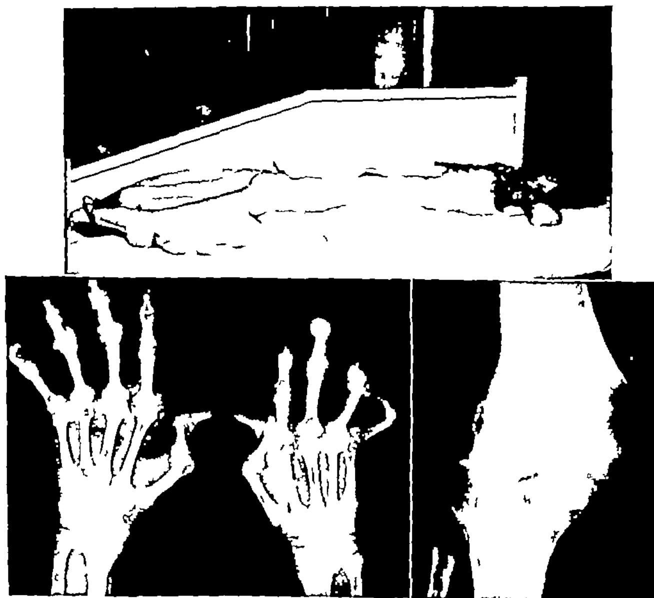


Fig 355 (*Top*) Case C. P., male, aged 36 exhibits a severe form of rheumatoid arthritis, implicating all the articulations. The spine is a rigid bony column. Also bony ankylosis has occurred in both hips and knees. (*Bottom, left*) Observe the osseous ankylosis of the metacarpophalangeal joints of the index fingers, the ankylosis of the wrists the intercarpal joints and the distal interphalangeal joints and the subluxation of some of the interdigital joints. (*Bottom right*) Left knee joint. The tibia is subluxated rotated externally and flexed on the femur Bony ankylosis has occurred in the position of deformity

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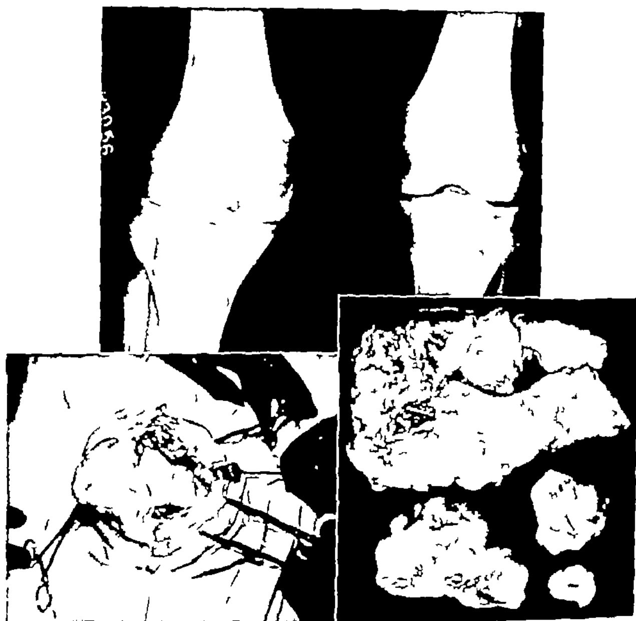


Fig 354 (*Top*) Rheumatoid arthritis of the right knee joint. Observe the narrow joint space and the spotty demineralization of the distal end of the femur and the proximal end of the tibia. This joint exhibited a flexion contracture of 20 and an external rotation deformity of the lower leg Compare with the noninvolved left knee joint. (*Bottom left*) Appearance of the right knee upon exposure of the joint Note hyperplastic and thickened synovial membrane this is even more apparent in the specimen removed (*Bottom, right*) Tissue removed from the joint depicted herein. Note the pronounced thickening and the hyperplasia of the synovialis.

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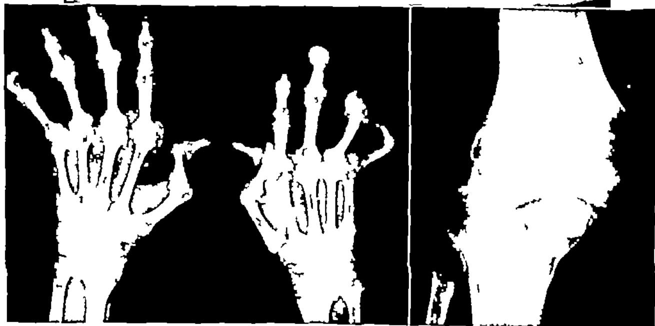


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producing fibrous ankylosis The destructive action of the panus above and the proliferation of the narrow connective tissue below the articular surfaces leave in their wake cartilage which is eroded, pitted, frayed and thinned This destructive process is enhanced by the action of chondroclasts and fibroblasts which arise in the panus and absorb the articular cartilage the intensity of the activity of the chondroblasts varies with the acuteness of the disease process The fibrous tissue stretching from one articular surface to the other converts the joint cavity in many intercommunicating pockets

Some areas of connective tissue, particularly those in the marrow spaces undergo metaplasia, forming osteoid tissue which follows the granulation tissue into the joint cavity, later, the osteoid tissue is converted into cartilaginous and bony trabeculae Union occurs between the opposing surfaces, which may be cartilaginous or bony In large joints such as the knee all three varieties of ankylosis may be present concurrently in different areas namely, fibrous cartilaginous and bony In some instances osteoblastic activity is very pronounced, according to Nichols and Richardson, coincident with the aforementioned alterations in the synovialis, the subchondral bone and the cartilage perichondral proliferation occurs, producing cartilage and bone this is challenged by other workers (Allison and Ghormley) who believe that the changes are too widespread to originate in the perichondrium Moreover, many observers do not believe that the gliding surface of the articular cartilage can be considered as a distinct and separate cartilage layer, designated the perichondrium To a lesser degree the proliferative reaction of the connective tissue also involves the fibrous capsule which becomes markedly thickened The capsule is also permeated with plasma and lymphoid cells and numerous capillaries With maturation of the granulation tissue, the capsule is transformed into a thick, dense, fibrous structure

Much emphasis has been laid on the presence of numerous round-cell leukocytes comprising lymphoid and plasma cells in the synovialis in cases of rheumatoid arthritis. These appear as diffuse or focal collections or nests which Allison and Ghormley have described as pathognomonic of proliferative arthritis. It has been shown that the foci of round cells are not perivascular and that they tend to collect at numerous areas in the subsynovial stratum, forming follicles of varying size (Fig 356) Although this is a common finding in rheumatoid arthritis many workers are convinced that focal collections of lymphoid cells are not diagnostic of the disease. Jordan believes that the lymphocytic reaction is non specific.

It is interesting to note that the bony trabeculae in the affected extremity when examined microscopically retain their normal size and are not reduced in number The diffuse loss of mineral observed roentgenographically is generally believed to be the result of disuse and the inflammatory hyperemia Occasionally, a spotty loss of calcium is demonstrable in the roentgenograms, it is not unlike the bone changes seen in Sudeck's bone atrophy This observation has lead some observers to believe that the bony rarefaction is due to abnormal vasoconstriction caused by local sympathetic activity It may well be that sympathicotonia, together with disuse, are the causative agents responsible for the profound demineralization so frequently encountered in severe cases of rheumatoid arthritis

Prognosis

Because the true causative factor of rheumatoid arthritis is not known, the prognosis should be guarded in every instance However with an intelligent approach to the problem co-operation of the patient and a well planned therapeutic regimen, a



Fig 356 Photomicrographs (*left* × 100 *right* × 200) of the synovial membrane obtained from a case of rheumatoid arthritis. The synovial and the subsynovial strata are markedly thickened the granulation tissue is rich in lymphoid and plasma cells. Observe the focal collection of these cells forming follicles of varying size

of severe joint involvement may show bony ankylosis of the joint with deformity In the knee joint ankylosis of the patello-femoral joint may also be discernible (Fig 355)

Pathology and Pathogenesis

Nichols and Richardson noted that the pathologic changes in rheumatoid arthritis *were proliferative in nature, implicating the* synovialis and the endosteum This is in contrast with the alterations which they observed in the degenerative arthritis in which the articular cartilage is primarily involved. Marked proliferation of the synovial membrane occurs so that it forms numerous folds and villi giving it a velvetlike appearance Occasionally the villi are bulbous or branching If their bases become *necrotic due to obliteration of the blood* vessels in the pedicles the villi may drop into the joint cavity as free bodies In some *cases numerous rice bodies are encountered*

This inflammatory tissue comprises gran*ulation tissue rich in lymphoid* and plasma cells it extends to the periphery of the articular cartilage from which it advances across the articular surface toward the center forming an irregular panus (Fig 356) Areas of intact cartilage are demonstrable between the prolongations of the panus Synchronously with the changes in the synovial membrane proliferation of the connective tissue occurs in the endosteum immediately below the articula surfaces some observers believe that the alterations in the synovial membrane antedate slightly those in the epiphyseal marrow Formation of a panus over *the articular cartilage is a* characteristic feature of rheumatoid arthritis Wherever the panus comes in contact with cartilage, solution of this tissue occurs This is also true of the granulation tissue *which forms in the endosteum*, destruction of the cartilage ensues as this tissue advances on its deep surface The under surface of the cartilage is exposed by the action of osteoclasts which increase in *number in the marrow* spaces of the subchondral bone and destroy first the articular cortex and then attack the cartilage *Focal collections* of round cells are found in great numbers in the proliferating connective tissue of the endosteum The panus tends to obliterate the joint space by binding together the opposing articular surfaces with granulation tissue which later is converted into dense fibrous tissue thereby

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Some areas of connective tissue, particularly those in the marrow spaces undergo metaplasia, forming osteoid tissue which follows the granulation tissue into the joint cavity, later the osteoid tissue is converted into cartilaginous and bony trabeculae Union occurs between the opposing surfaces, which may be cartilaginous or bony In large joints such as the knee all three varieties of ankylosis may be present concurrently in different areas, namely, fibrous, cartilaginous and bony In some instances osteoblastic activity is very pronounced, according to Nichols and Richardson coincident with the aforementioned alterations in the synovialis the subchondral bone and the cartilage perichondral proliferation occurs producing cartilage and bone this is challenged by other workers (Allison and Ghormley) who believe that the changes are too widespread to originate in the perichondrium. Moreover many observers do not believe that the gliding surface of the articular cartilage can be considered as a distinct and separate cartilage layer, designated the perichondrium To a lesser degree the proliferative reaction of the connective tissue also involves the fibrous capsule which becomes markedly thickened The capsule is also permeated with plasma and lymphoid cells and numerous capillaries With maturation of the granulation tissue the capsule is transformed into a thick, dense fibrous structure

Much emphasis has been laid on the presence of numerous round-cell leukocytes comprising lymphoid and plasma cells in the synovialis in cases of rheumatoid arthritis. These appear as diffuse or focal collections or nests which Allison and Ghormley have described as pathognomonic of proliferative arthritis It has been shown that the foci of round cells are not perivascular and that they tend to collect at numerous areas in the subsynovial stratum forming follicles of varying size (Fig 356) Although this is a common finding in rheumatoid arthritis many workers are convinced that focal collections of lymphoid cells are not diagnostic of the disease Jordan believes that the lymphocytic reaction is non specific

It is interesting to note that the bony trabeculae in the affected extremity when examined microscopically retain their normal size and are not reduced in number The diffuse loss of mineral observed roentgenographically is generally believed to be the result of disuse and the inflammatory hyperemia. Occasionally a spotty loss of calcium is demonstrable in the roentgenograms, it is not unlike the bone changes seen in Sudeck's bone atrophy This observation has lead some observers to believe that the bony rarefaction is due to abnormal vasoconstriction caused by local sympathetic activity It may well be that sympathicotonia, together with disuse are the causative agents responsible for the profound demineralization so frequently encountered in severe cases of rheumatoid arthritis

Prognosis

Because the true causative factor of rheumatoid arthritis is not known, the prognosis should be guarded in every instance However with an intelligent approach to the problem co-operation of the patient and a well planned therapeutic regimen, a

great majority of the patients can be relieved of their acute suffering and some correction of deformed limbs can be achieved so that useful function is restored and the general health can be improved. A small number of patients attain excellent results but a patient s hopes must not be elevated too high since such cures are indeed rare In advanced cases with severe joint alterations restoration of satisfactory function is hardly to be expected since the changes in the cartilage and the osseous elements are permanent, regeneration of the affected tissues does not occur On the other hand in recent cases with only minimal joint changes deformities can be prevented, and acceptable restoration of function can be anticipated if the correct plan of therapy is instituted In old cases with residual deformities of the joints treatment is designed primarily to give the patient some relief of pain, only symptomatic measures can be employed

The prognosis is governed by many factors such as the body type and the general health of the patient the presence or the absence of active foci of infection the resistance the age and the mental stability of the patient and the intensity and the duration of the disease the severity of the deformities and finally the co-operation of the patient More can be anticipated in early cases certain factors argue for unfavorable prognosis These are heredity nervous instability asthenic individuals with poor general health, profound debility of the patient marked atrophy of muscles and bones long duration of the disease structural deformities allergic manifestations and finally failure to attain the co-operation of the patient The possibility of relapses of the disease after long periods of inactivity always must be considered when the prognosis is evaluated

Treatment

No other human affliction has been treated with more therapeutic agents than chronic joint disease It is safe to say that every herb, drug or chemical agent by man, at some time or other administered to the arthritic patien known modality has been employe system of the body has been attac barring the mind In spite of all th the over all picture of treatment is satisfactory however, more recent evidence has been produced to bol morale of the many investigators in in this subject

It is important to remember formulating any method of treatm patient must be considered as a Rheumatoid arthritis primarily is temic disease although the joint ma tions predominate the clinical pict are usually crippling they compri one facet of the disorder Adequate r ment should embody measures to the patient s general physical sta eradicate the causative agent or minimize its destructive and debi influence to prevent deformities an store maximum restoration of func the involved joints These should aims of treatment unfortunately, no specific agent has been found th remove the etiologic factor which unknown to us Also even under th meticulous outline of therapy the sults evaluated in terms of useful fu of the affected limbs is far from s tory Nevertheless much can be d improve the lot of these patients.

In the successful execution of an of therapy it is highly important t the confidence of the patient and press upon him the fact that succ failure depends in a large measure the co-operation shown and the re bility that he assumes This mean great effort must be expended by the vidual in adjusting himself to a new v life It may mean that habits whic vided certain pleasures must be d tinued

General Measures Every effort s be made to improve the patient s en

ment. His physical and mental activities should be so regulated that minimal stress is inflicted on a debilitated body and mind This embraces moderation in the intake of foods which should provide a well-balanced diet rich in calcium, vitamins and proteins and low in carbohydrates. Although evidence is lacking that vitamin deficiencies play a role in the etiology of the disease, it is common knowledge that in chronic diseases a deficiency may exist which tends to lower body resistance and favors debilitated status This can be corrected by simple diets rich in vitamins Foods such as milk, eggs, meats, whole wheat bread cereals citrus fruits, tomatoes butter, liver and fish will supply the necessary vitamin intake Ascorbic acid may be given 50 to 200 mg daily to overcome the vitamin C deficiency which is reported to be frequently present in rheumatoid arthritis The foods that must be eliminated are those which are known to precipitate allergic phenomena in the patient. Excessive use of tobacco or alcoholic beverages must be curtailed this will tend to improve the general physical status All bacterial foci of infection should be eradicated. This does not mean that healthy teeth should be sacrificed or that inoffensive tonsils should be extirpated

As noted previously physical and mental rest is the most important general measure in the treatment of this disease Depending upon the severity of the disease this may mean complete bed rest for weeks or months to long hours of night rest which may be supplemented by several hours of rest in the middle of the day It is interesting to note the rapid decrease in swelling of affected joints following simple bed rest Pemberton and Scull are of the opinion that this phenomenon is the result of a negative water balance which is induced by the recumbent position. Patients must learn to regulate their activities so that they never become fatigued they must not be left to their own discretion when to rest but should follow a specific regulated schedule They should be taught the most favorable recumbent positions, for instance, a firm mattress is an essential requisite, a low pillow under the head is sufficient, no pillows should be allowed under the knees, since this favors the development of flexion contractures.

In the event that muscle spasm and pain interfere with the patient's rest, light molded plaster splints may be applied to immobilize the painful joints These should be used also as a prophylaxis against development of deformities They should be so applied that they can be removed readily in order to permit exercising the joint.

The program should include exercises executed by the body as a whole and by the affected joint This is a very important facet of the therapeutic plan. Exercising the whole body tends to establish normal metabolisms of all tissues and systems and prevents severe atrophy of bone and muscles Deep breathing and underwater exercises are especially useful The affected joints should be moved through as great an arc of motion as possible several times a day preferably, this should be performed actively by the patient It is important to remember that the patient never must be fatigued, and the exercises must not extend beyond his tolerance of pain Also, the exercises should be performed on a regulated regimen, preferably under supervision Exercises to improve body posture and to develop muscle tone and volume should be taken by the ambulatory patient, such measures enhance restoration of good general health

Microcytic hypochromic anemia is a concomitant feature of rheumatoid arthritis. The most valuable therapeutic measure to correct this deficiency is whole blood. Small transfusions (250 cc. of whole blood) not only supply red blood cells but they also provide other factors which *improve* the well-being of the patient, raise the body resistance and promote the general health. Such transfusions should be given as frequently as is deemed necessary if there are

no contraindications Transfusions given at intervals of 7 to 10 days assure the most beneficial effects

The effect of heat on the vasomotor system is the production of vasodilation which relieves pain and muscle spasm This beneficial effect of heat in the arthritic patient is common knowledge and has been responsible for the development of numerous measures local and general designed to increase the local or body temperature General vasodilation may be produced by the administration of such drugs as histamine or niacin foreign proteins and typhoid vaccine may be given intravenously or the patient may be inoculated with malaria More recently fever cabinets have been conceived to produce general vasodilation Sympathectomy, the surgical approach to this problem, has not been effective in rheumatoid arthritis

Medicinal Agents. In spite of numerous medicinal agents employed by man in the treatment of chronic arthritis no specific medication has been discovered When favorable results are reported and the benefits derived are credited to any one agent or method one must temper this conclusion with the knowledge that chronic arthritis is a disease in which remissions are very likely to occur and that reactivation of quiescent states of the disorder is a common occurrence One must remember also that the apprehensive, unstable arthritic patient is vulnerable to suggestive therapy and the improvement may be psychologic Nevertheless by the method of trial and error certain drugs have proved to be useful Agents which relieve pain and muscle spasm increase local and general circulation improve metabolic processes and provide rest of body and mind are useful in the treatment of rheumatoid arthritis

Salicylates have stood the test of time they relieve pain and rarely produce any undesirable sequelae The most common salicylate administered orally is acetyl salicylic acid Salicylates may also be administered intravenously

Codeine is an excellent drug to relieve pain its analgesic effect is enhanced when given in combination with aspirin Other opiates, such as morphine or Demerol should be used sparingly in view of their tendency to produce addiction When hypnotics are desirable, the barbiturates usually suffice

Procaine given intravenously has been reported to relieve pain and improve the morale of patients with chronic arthritis It is administered in 0 1 per cent solution in normal saline The amount advocated by Granbard is 4 mg of procaine per kilogram of body weight this worker also gives large doses of ascorbic acid with the procaine Graut uses even larger doses of procaine believing that larger doses give better results This form of therapy is employed in both degenerative and rheumatoid arthritis it may be given daily, weekly or as indicated according to some workers the best results are obtained in the degenerative form of chronic arthritis In rheumatoid arthritis improvement is less pronounced and only temporary In order to prevent procaine reactions, Nembutal (3 grains) is given 30 to 45 minutes prior to the administration of the procaine Such reactions always must be anticipated and proper measures such as fluids and oxygen should be in readiness to meet the emergency This method of therapy is not innocuous severe vasomotor collapse, cerebral irritation resulting in delirium and convulsions and even cases of death have been recorded.

At one time sulfur in colloidal form was used widely in the treatment of arthritis. Its popularity was based on the belief that it was capable of detoxifying noxious metabolites such as indole However this drug has failed to produce lasting benefits in the rheumatoid patient and therefore has been discarded It is interesting to note that following the administration of sulfur the hemoglobin s function to transport oxygen is enhanced greatly Hence the benefits derived by some patients may be explained

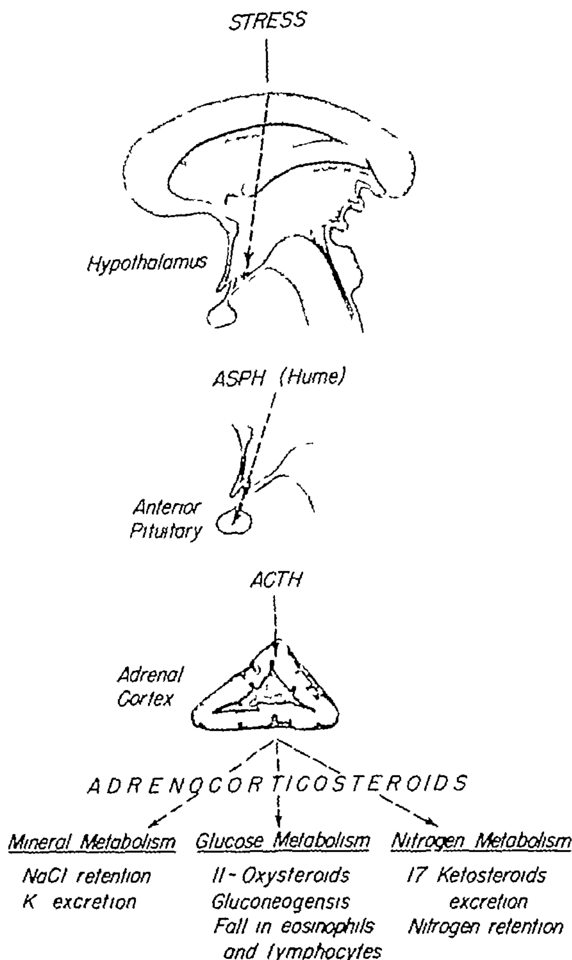


FIG 351 Hypothalamic pituitary adrenal cortex axis (Redrawn from Traut, E. F Rheumatic Diseases St. Louis, Mosby)

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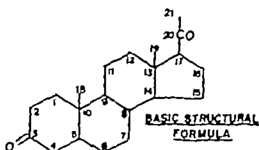
are of the opinion that the beneficial results obtained could be duplicated by many other forms of therapy or by simple currently used measures designed to improve the general health, to limit further joint destruction and to improve joint function In addition, clinical experience reveals that gold is far from a safe agent to use in the treatment of rheumatoid arthritis Numerous complications, some of which terminate fatally, are known to occur Notably among the unfavorable sequelae indicating gold intoxication are pruritus, stomatitis and ulcerative colitis less commonly encountered are exfoliating dermatitis, granulocytopenia nephritis purpura hemorrhagica toxic jaundice and multiple peripheral neuritis.

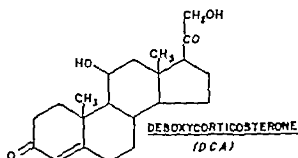
The usual method of administration of gold is the intramuscular route in the form of myochrysine or solganol B oleosum both contain 50 per cent gold The mechanism of the beneficial effects of gold on body tissues is not understood Gold like so many other therapeutic agents which were used with great enthusiasm in the past and then discarded, is rapidly falling into disfavor

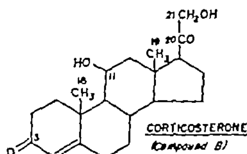
ACTH and Cortisone. The work of Hench et al with cortisone and the pituitary adrenocorticotropic hormone (ACTH) in the treatment of rheumatic fever and rheumatoid arthritis reveals that the adrenal cortex and the pituitary gland in some way are associated closely with these pathologic states this may be a direct or indirect relationship It is now widely known that the hypothalamic-pituitary-adrenal cortex axis is responsible in a large measure for the ability of the body to respond to crises this response is designated the adaptation syndrome (Fig 357) It is clinical knowledge that conditions which stimulate the function of the adrenal cortex in cases of rheumatoid arthritis may induce remissions of the disease process. Notably among these conditions are pregnancy hepatocellular jaundice severe trauma and surgical procedures. This observation leads one to conclude that the same hormonal phenomenon instrumental in meeting situations of stress also is capable of inducing remissions in rheumatoid arthritis Numerous crystalline steroids (28) have been extracted from the adrenal cortex, and there is evidence for the belief that many more steroids exist which up to this time have not been isolated The known steroids have profound effects on metabolic processes of the body Briefly, they can be divided into three groups The first group is concerned primarily with electrolyte and fluid balance, causing retention of sodium and chloride and excretion of potassium, the principal steroid is 11-desoxycorticosterone The acetate of this steroid has been synthesized and placed on the market under the trade name Doca or DCA. The second group of steroids govern in a large measure the intermediary metabolism of protein, carbohydrates and fat They possess an *oxygen* molecule at carbon eleven in one of two combinations a keto or hydroxy form, and comprise the corticosteroids included in the corticosterone series also referred to as glycocorticoids In this group are compound E (17 hydroxy, 11-dehydroxycorticosterone) also designated cortisone and cortone, and compound F (17 hydroxycorticosterone, Hydrocortone) (Fig 358) Other effects of these corticosterones are (1) inhibition of growth in young animals and temporary inhibitory influence on the production of ACTH by the anterior pituitary gland and (2) destruction of lymphoid tissue, the number of eosinophils and lymphocytes in the blood is reduced Steroids in the third group (etiocholane) exhibit an androgenic and anabolic function The adrenal cortex is the chief source of androgens in the male and the female Albright referred to the androgens derived from the adrenal cortex as "N" hormone, its influence results in retention of nitrogen, phosphorous sodium, chloride and potassium also it produces masculinization.

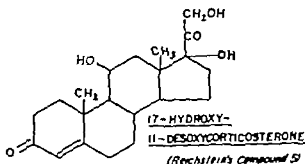
by the improvement of peripheral circulation induced by the sulfur

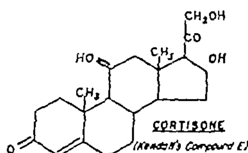
The diversified reports recorded by many clinics both here and abroad, relative to the value of gold in the treatment of rheumatoid arthritis *lead one to conclude that the* use of this heavy metal has failed to produce the desired results Chrysotherapy has had a long clinical trial, and, in spite of the enthusiastic reports of some most workers

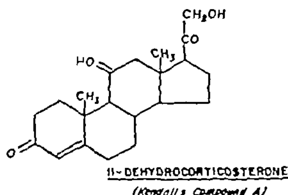












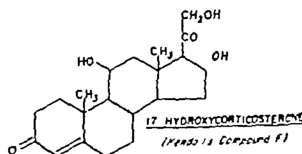


Fig 358 Adrenal steroids compared with corticosterone Radicals or substances added to corticosterone taken as a basis are in heavy type Those deleted from the basic corticosterone formula are in dotted lines. (Traut E. F Rheumatic Diseases St. Louis Mosby)

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When the adrenal cortex is stimulated by injection of the anterior pituitary hormone *ACTH*, increased production of the corticosterones ensues which has a dramatic favorable effect on rheumatoid arthritis rheumatic fever and other diseases in this group The same results are obtainable *by the injection of cortisone* or compound F (Hydrocortone) It has been shown that these agents influence those diseases of the connective tissues which appear to be responses to body stress and some disorders which are not related to rheumatoid disease gouty arthritis is affected favorably by these agents ACTH used for long periods may cause hypertrophy of the adrenal cortex on the other hand elevated blood levels of cortisone have a tendency to cause atrophy of the adrenal cortex and suppress the function of the anterior pituitary *which is reflected by the* decreased amounts of ACTH In some instances the use of compound E or F or ACTH has suppressed completely the activity of rheumatoid arthritis as manifested in the relief of symptoms disappearance of local swellings, restoration of joint function improvement of general health and disappearance of laboratory evidence pointing to activity of the disease process The beneficial response noted after the injection of ACTH in cases with allergic manifestations is in part the result of increased formation of histaminase by the adrenal cortex if there are no contraindications the significance of ACTH in such cases is obvious

Continued clinical and laboratory investigations reveal that cortisone and ACTH have failed to produce the brilliant results anticipated by some workers and in a way have disappointed both *the profession and* the laity Nevertheless ACTH and cortisone are without question the most significant agents isolated by man in the long war against rheumatoid diseases and other disorders of the connective tissue The amount of improvement derived from the use of these drugs may be sufficient to transform an individual with complete invalidism to one capable of at least caring for himself, thereby regaining his dignity and usefulness. It is now *established that* upon cessation of the administration of the hormones, exacerbations of rheumatoid arthritis generally ensue, and in occasional cases the manifestation after stopping the treatment may be more severe than those before therapy was started or increased activity may occur during the period that the drugs *are administered this has occurred* even when large doses were given In most cases the hormones must be administered indefinitely in order to obtain maximum benefits and to prevent relapses Some workers are experimenting with other agents such as gold or vaccines to main*tain clinical remissions after they have been obtained with ACTH or cortisone* In addition many side reactions have been recorded most of which can be reversed by cessation of the therapeutic agents The high cost of the hormones particularly ACTH is a factor that must be considered when a plan of therapy is formulated.

In most cases of rheumatoid arthritis administration of ACTH or cortisone is followed by a prompt beneficial response however in spite of intensive and prolonged treatment some joints exhibit evidences of activity such as swelling tenderness and painful motion The psychic improvement in many cases is dramatic euphoria and a feeling of well being are characteristic mental states in *patients under active treat*ment however in rare instances mental depression may occur Changes in the mental state are the first favorable observations noted after treatment is initiated next the beneficial alterations in the affected joint are manifest and lastly the sedimentation rate begins to approach normal This laboratory test together with the extent of depression of the eosinophils are good indications of the effectiveness of the treatment depression of the *eosinophil*

and lowering of the sedimentation rate are favorable indices Under treatment the red cell count and the hemoglobin rise, and the globulin levels lower, however, the albumin globulin ratios rise

The best results with the use of ACTH and cortisone are observed in patients with minimal structural deformities in the affected joints These drugs do not have the ability to restore degenerative cartilaginous and osseous tissue Although in many patients with advanced joint changes pain is reduced in intensity, function of the articulation is improved, and the general health is enhanced, yet the structural alterations in the joints are not affected The mechanism of ACTH and cortisone in producing favorable responses in rheumatic diseases is not known these drugs must be considered as symptomatic medication There is no conclusive evidence that there is a deficiency in the production of these hormones in rheumatoid arthritis or other collagen diseases. Clinical observations disclose that the prime action of ACTH and cortisone is suppression of the pathologic process they do not remove it. It is believed that this phenomenon is brought about by decreasing the ability of mesenchymal tissue to respond to harmful factors As pointed out by Traut this concept receives support from the observation that in cases under treatment the ability of hyaluronic acid to react to hyaluronidase is decreased

Now cortisone may be given in tablet form (Cortone) by mouth. The dosage and the duration of the treatment vary with each patient In general in severe or moderately severe cases Traut recommends the following course "The first day 100 mg is given every 8 hours The second day 100 mg is given every 12 hours The dose on the third day is 100 mg given at one time or 25 mg 4 times daily I may then try to reduce the dose to 75 mg daily and after at least 4 days of sustained improvement, I make the dose 50 mg daily Most patients with severe rheumatoid arthritis require 100 mg of cortisone daily for an indefinite time. Moderately severe cases have been able to maintain their improveemnt on 75 mg of Cortone as a daily dose After several weeks I have been able to reduce the dose in some patients to 50 mg and even 25 mg I have never felt justified in reducing the dose further or stopping the drug in severely ill patients with rheumatoid arthritis chosen by me for this type of therapy"

Unfavorable Reactions. ACTH is more prone to produce undesirable effects than cortisone, most of these are physiologic in nature and should be anticipated. Some of the undesirable effects are hirsutism, rounding of the face (moon face), acne, amenorrhea and pigmentation of the nails and the skin. Cases in which treatment has continued over a long period may develop manifestations of Cushing's syndrome, characterized by hypertension, osteoporosis, diabetes and virilism The demineralization (osteoporosis) is evoked by the negative calcium balance induced by the hormones ACTH and cortisone have been credited with interfering with normal healing of wounds this has not been confirmed by other observers The author has had several occasions to administer cortisone following major surgical procedures Evidence of delay in the healing of tissues never was manifested grossly in these cases

Contraindications ACTH and cortisone are contraindicated in diabetus mellitus hypertension heart failure chronic nephritis, psychoses infections peptic ulcers pregnancy, tuberculosis and septicemia

Compound F (Hydrocortone) Instillation of small quantities of this hormone (1 cc.) into painful, swollen joints of individuals with rheumatoid and degenerative arthritis relieves the pain and the swelling in a great majority of the cases The author has employed this mode of treatment and has been impressed favor

ably with the comfort and the usefulness of the limbs that the patients attain

Vaccines Although there is no conclusive evidence that rheumatoid arthritis is produced by some forms of bacteria its inflammatory nature suggesting an infectious *process cannot be denied* The rationale of the use of vaccines is based on this observation Streptococci more than any other *bacteria have been incriminated as the* etiologic factors The infectious theory of origin is keenly disputed by some authors Nevertheless *skin tests disclose a hyper* sensitiveness to streptococci for this reason vaccines may be considered as agents employed in allergic treatment essentially they are desensitizing media. Some workers have compared vaccines with other measures producing stress which in many instances are followed by amelioration of the disease process in this category must be placed shock, fever, trauma and ACTH and cortisone Most rheumatologists employ some vaccine in the treatment of rheumatoid arthritis Vaccines in common use today are nonspecific, specific autogenous or stock varieties They may be in the form of bacterins which are suspensions of dead bacteria as products of bacterial growth obtained by washings of centrifuged bacterial suspensions or as filtrates of the disintegrating bacteria. Before the role of the anterior pituitary and the adrenal cortex in rheumatoid arthritis was understood vaccines were given *in the belief that anti* bodies were formed or the host's resistances were increased against reactions produced *by the noxious agents Now some observers* point out that bacterial proteins may initiate a body reaction similar to that observed *in shock or fever* which may induce the adrenal cortex to increased activity this may be the result of direct stimulation of the adrenal cortex or through the medium of the anterior pituitary On the other hand *failure to depress the* eosinophils in the blood is believed by some to indicate that vaccines fail to stimulate the adrenal cortex in any appreciable degree In spite of the existing controversy most men treatin rheumatoid arthritis employ vaccines in rheumatoid arthritis as desensitizing agents in bacterial allergy Also they are used to prolong the remissions attained with ACTH and cortisone

Parathyroidectomy The osteoporosis of the skeleton so frequently observed in rheu*matoid arthritis has been* the subject of much speculation Most workers are in agreement that the demineralization is the *result of disuse and, as pointed out by* de Takats increased sympathetic tone may play a part However, some men have interpreted this *observation as a manifesta*tion of hyperparathyroidism and have even reported findings of hypercalcemia in cases of rheumatoid arthritis Consistent changes in the content of calcium phosphorous or phosphatase in cases of rheumatoid arthritis have not been confirmed by other investigators Nevertheless parathyroidectomies have been performed for ankylosing polyarthritis and Marie-Strümpell spondylitis with subsequent improvement which was attributed to removal of the parathyroid glands At the present time there is general agreement that hyperparathyroidism plays no part in the pathogenesis of rheumatoid arthritis and parathyroid therapy is not to be recommended in the treatment of chronic joint diseases

Sympathectomy It is common knowledge *that vasodilation is desirable* In rheumatoid arthritis this enhances metabolic processes in the affected tissues re*moves toxic agents* and supplies nutrition to the part Resection of the sympathetic ganglia and rami was conceived to produce this effect However the procedure has failed to produce lasting results and has been discarded

Local Measures. Massage has long been recognized as the best form of local therapy in patients with chronic joint diseases The prime objective of this form of mechanotherapy is to improve and *maintain the*

circulation of the tissues of the affected joint It is a good substitute for normal motion in stimulating the physiologic processes of the joint structures. Massage tends to overcome the vasoconstriction which is a constant concomitant feature in rheumatoid arthritis Fluids both intracellular and extracellular, which accumulate in tissues because of lack of normal muscular contraction are dispersed by massage At the same time, the soothing effect of massage permits some joint motion which is so essential in preventing the formation of adhesions The form of massage and the duration of the treatment is governed by the physical status of the patient and the intensity of the inflammatory process Massage should not be given directly over the joint but rather over the soft tissues distal and proximal to the joint. In the case of the knee joint, the quadriceps and the flexors of the thigh and the muscles of the calf should be given particular consideration Massage should be gentle and not forceful it should not initiate accentuation of the inflammatory process and it never should fatigue the patient A valuable form of massage is provided by the whirlpool bath Members of the family should be taught the technic of the form of massage desired so that the patient may receive daily treatments at home Numerous materials have been advocated as lubricants however, one is as good as another, since the benefits derived are the result of the manipulation of the tissues and not the result of the lubricants employed Massage is more efficacious if heat, particularly radiant heat is used before and a period of rest is enforced *after the treatment*

Exercises should be executed during all stages of the disease they should be performed within the tolerance of pain, and the patient must not be unduly fatigued. A knee joint should be moved actively and passed through its arc of painless motion several times daily this is facilitated if heat and massage precede the exercises Inflamed joints should not be permitted to bear weight, this induces muscle spasm, pain and swelling Protected weight bearing is allowed only when swelling and pain have subsided and weight bearing is tolerated without recurrence of these features. The therapeutic pool with its warm water facilitates the performance of active exercises, the water supports the limbs during the exercises, and the warmth enhances muscle relaxation and reduces muscle spasm. Passive exercises should be avoided if possible, they do not stimulate muscle contraction, and the patient expends no effort or will power in their execution Often they are harmful because they evoke pain and may tear tissues On the other hand active exercises are a stimulus to normal physiologic function, they increase general body metabolism and enhance local circulation. In addition, active exercises are usually accompanied by a favorable psychologic response the satisfaction that accompanies achievement improves the patient s morale

Patients with rheumatoid arthritis never must be allowed to lose joint motion, even in the early stages of the disease The joints should be exercised through the full range of motion at least once daily If the importance of this treatment is explained to the patient, invariably he will co-operate fully All exercises should be performed slowly and under control of the patient and within his tolerance of pain Particular attention is paid to the flexor and the adductor muscles, since these are the chief offenders in producing deformities When acute and subacute symptoms subside the intensity of the exercises is increased these are always performed below the reaction level of the joint. Occupational therapy provides varied forms of exercises and restores confidence in the patient

Prevention and Management of Knee Deformities

The most essential facet of a plan of therapy is *prevention of deformities*, pre-

vention is achieved more readily than correction of structural deformities which invariably follow moderately severe and severe forms of neglected cases of rheumatoid arthritis Pain and muscle spasm are the two important factors responsible for deformities in the early stages of the disease Pain forces the patient to seek a position of comfort which is usually one of flexion muscle spasm a protective mechanism associated with pain maintains the deformity If the deformity is not corrected contraction of the capsule, the ligaments, the tendons and the muscles ensues now the deformity is fixed and difficult to overcome It becomes apparent that temporary splinting with the joint in the desired position is a necessary requisite to avoid soft tissue contractures and to relieve pain The knee joint should be immobilized in full extension Except in the cases with acute inflammatory reactions the splints should allow some form of active exercise of the limb and the affected joints This is achieved best by posterior molded plaster splints which are held to the limb by elastic bandages (Ace bandages) the splint may be removed once or twice a day to permit voluntary motion at the knee joint and active contraction of the quadriceps and the flexors of the knee Contraction of the quadriceps (quadriceps drill) and straight leg raising can be performed throughout the day while the splint is in situ Exercises not only increase circulation of the part and restore muscle tone but they also prevent the formation of intra articular adhesions which are the precursors of fibrous and bony ankylosis Rest of the part is essential between the exercise periods It must be remembered that treatment of the joints is only a small part of the general treatment and it must be carried out in conjunction with measures designed to treat the body as a whole Acute cases with severe pain and marked local inflammatory manifestations should be given total rest A cast may be applied from the groin to the toes to prevent deformities, this may mean a period of several weeks After the acute manifestations have subsided the cast is bivalved, and voluntary exercises as described above are begun Exercises are the only measures that will overcome muscle atrophy, weakness and loss of voluntary control of groups of muscles such as the quadriceps they should be considered as the most important instruments in the physician's armamentarium Weight-bearing is permitted only when the acute manifestations have subsided and muscle tone and power have been restored In the beginning weight bearing should be protected crutches are far superior to knee cages and braces since the latter tend to induce more atrophy and weakness in the quadriceps. Cages and braces should be worn only when it is apparent that recurrence of the deformity is inevitable without continuous splintage and voluntary exercises are not sufficient to prevent the recurrence If the simple aforementioned orthopedic measures are carried out deformities can be prevented in all cases also a useful range of motion may be preserved In the event that massive destruction of cartilage is evident and fibrous or bony ankylosis is inevitable the knee should be immobilized in a plaster cast holding the joint in the optimum position of function (12 to 15° of flexion) This also applies to all other joints As a rule deformities can be prevented in cases encountered and treated adequately during the first 6 months of the disease

Correction of Knee Deformities

Once a deformity of the knee joint is established varying degrees of dysfunction ensue depending upon the severity of the contracture Generally the deformity of the knee is a flexion contracture in occasional instances it is an extension contracture The latter is usually the result of immobilization of the limb in full extension or follows forceful correction of a previous flexion contracture If a knee cannot be

flexed more than 10° beyond full extension, the deformity must be considered as an extension contracture This deformity oc curred in 28 per cent of the cases studied by Kuhns Although some authorities point out that 10° of flexion is compatible with good function and rarely leads to significant symptoms clinical experience discloses that even this amount of contracture puts the knee joint to a mechanical disadvantage because full contracture of the vastus medialis is not possible Loss of the stabiliz ing effect of the vastus medialis makes the knee vulnerable to episodes of giving way moreover, as pointed out by Holbrook walking on a limb with 15° of flexion or over is followed by a progressive increase in the amount of flexion deformity It be comes apparent that the goal in treatment of flexion deformities of the knee joint should be restoration of full extension On the other hand one must admit that this aim may be difficult to achieve and in some instances impossible Most of the following observations recorded are essentially those noted by Kuhns in a study of 586 contrac tures of the knee found in 1,453 patients suffering with chronic arthritis

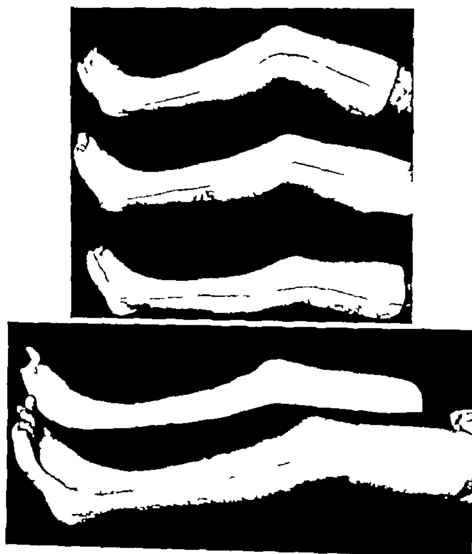


Fig 359 (*Top*) A series of casts achieving gradual correction of a flexion deformity of the knee joint. (*Bottom*) Posterior molded plaster splint to prevent flexion deformity If more nearly complete immobili zation is desired an anterior splint also may be added. These are held together with elastic bandages.

In all contractures there is shortening of the posterior capsule the muscles and the ligaments which if allowed to persist for several years is complicated by irreversible changes in the muscles Sixty per cent of the patients exhibit bilateral involvement of the knee joints whereas in 40 per cent one knee is implicated and the opposite knee is free of any deformity Flexion contractures of 34° or over produce the greatest amount of dysfunction symptoms of sprain are precipitated not only in the knee joint but also in hip and ankle joints In the event that concomitant deformities as subluxation or external rotation of the tibia, are present the disability is increased still further

Mild and Recent Contractures. Cases in which the flexion deformity cannot be corrected passively may be treated by a series of plaster casts this method is far more efficacious than the use of wedging casts or traction. The limb is placed in plaster from the toes to the groin (Fig 359) As the result of complete immobilization of the limb muscle spasm subsides After 2 days the cast is bivalved and the two halves are removed for short periods during which the limb is given heat, massage and active exercises. Particular attention should be paid to the quadriceps The author has found hot fomentations most valuable during this phase of the treatment motion always should be within the tolerance of pain Such a program is carried out daily until 10° or more of correction is obtained then a new cast is applied Maximum correction of the deformities by this method is usually achieved in 1 to 3 months Weight-bearing should not be allowed until the stabilizing apparatus of the knee joint are sufficiently strong to protect the joint against sprains and traumas incident to instability the most pertinent factor is the quadriceps muscle If a thigh caliper is deemed necessary when walking because of weak muscles every effort should be made to restore as soon as possible sufficient quadriceps tone and power to permit the thigh caliper to be discarded

When no correction is demonstrable after the use of a plaster cast for several weeks one must consider more radical methods in order to overcome the contracture Usually it is difficult to determine the resistance of contractures when the patient is examined the first time whether or not the plaster cast method is practical can be determined only by several weeks of trial

Severe and Old Contractures. Flexion contractures of long duration present more difficult problems when correction is contemplated Generally, the shortened fibrotic posterior capsule offers the greatest amount of resistance to any closed method. As pointed out by Kulowski flexion contractures of the knee usually exhibit deviations in three planes In the sagittal plane there are varying degrees of flexion of the tibia on the femur and in some instances posterior subluxation of the tibia The subluxation is usually noted in flexion deformities greater than 20° The normal deviation of the knee may be increased by contracture of the tensor fascia femoris and the biceps femoris muscles this component of the over-all deformity is in the frontal plane The external rotators of the knee (of which the biceps femoris is the most powerful) are stronger than the internal rotators In addition the biceps femoris is inserted at a more distal point than the internal rotators Contracture of the external rotators tends to force the flexed tibia into a position of external rotation in the horizontal plane Other factors favoring this last component of the deformity are relaxation of the ligamentous apparatus and the unwinding action of the cruciate ligaments when the tibia is rotated externally on the femur It becomes apparent that increased deviation posterior subluxation and external rotation of the tibia can occur only when the knee is fixed firmly and for a long period of time in the flexed position.

Numerous mechanical methods have

been devised to correct the aforementioned flexion deformities Many of these methods have been credited with good results others with bad The methods described herein are the ones that have given the author the best results An attempt is made to correct all flexion deformities without posterior dislocation of the tibia with a turnbuckle cast similar to that described by Kulowski If this fails or if posterior dislocation of the tibia occurs, a posterior capsuloplasty according to the method of Wilson is employed Surgical intervention is also utilized in flexion deformities with posterior subluxation of the tibia correction of the subluxation in these cases is achieved by skeletal traction as described by O'Donoghue. The aforementioned procedures are employed in cases which by roentgenographic study exhibit only minimal destruction of the articular surfaces In the presence of extensive alterations of the opposing cartilaginous surfaces an osteotomy is advocated by some workers believing that this procedure improves the line of weight bearing and reduces the intensity of the pain In the hands of the author this method has failed to provide sufficient

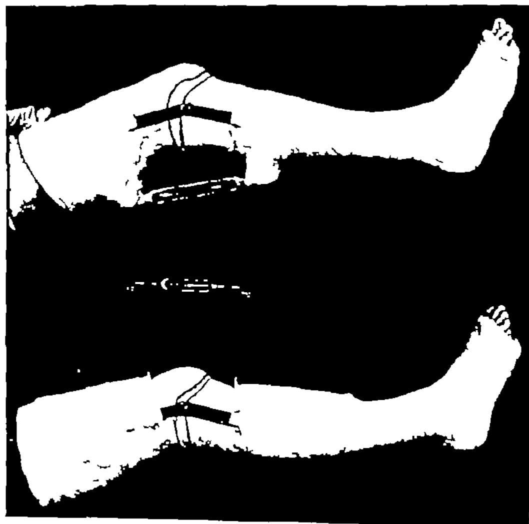


Fig 360 (*Top*) The usual method employed to correct fixed flexion contractures (Kulowski's method) Note the tonguelike projection of the proximal segment of the cast covering the *anterior surface* of the patella (*Bottom*) The turnbuckle is placed anteriorly, fixed to steel uprights. This method is utilized to attain the last few degrees of correction in cases offering great resistance at the terminal stages of correction This method was described by Quengel.

amelioration of symptoms to justify its continued use. In severely damaged joints arthrodesis is a useful procedure if the hip on the affected side and the opposite knee are not involved. However, unilateral involvement of the knees is not encountered frequently; also, the possibility always exists that the nonimplicated knee may be affected subsequent to the operation. These factors limit greatly the field of application of arthrodesis. The favorable results that have been reported recently following arthroplasties of knee joints in which nylon was employed as the interposing membrane are convincing enough to justify further investigation. The author's experience in this type of arthroplasty is too limited to express an opinion. However, the procedure as described by Kuhns and McKeever, D. C., is now under consideration and will be tried on cases of chronic arthritis with extensive joint destruction.

Correction With Turnbuckles and Hinges (Kulowski). The limb is immobilized in a long leg cast well padded over the patella, the heel and the dorsum of the foot; the cast extends from the toes to the groin. A hip spica is applied when the deformity is long standing and considerable resistance is anticipated. The cast should be light and molded to the configuration of the gastrocnemius muscle. After the plaster is hardened, the cast is sectioned at the knee joint in such a manner that a projection is left on the thigh portion which extends over the patella; this tends to distribute evenly the pressure over this region (Fig. 360). In cases with no subluxation of the tibia, the hinges and the turnbuckle are incorporated into the two segments of the cast in such a manner that the center of the hinges coincides with that of the knee joint, which for practical purposes can be considered as the center of the femoral condyles. Proper placement of the hinges maintains the center of motion at the joint. Correction by wedging casts without hinges is apt to shift the center of motion at the joint since when force is applied correction can be obtained only by stretching of the hamstrings. If great resistance is offered by the hamstrings, the center of rotation *shifts* from the center of the knee joint to the point of insertion of these muscles, thereby producing posterior subluxation of the tibia or increasing the deformity if it is already present. Properly placed hinges tend to maintain the center of motion at the knee joint; however, even with hinges in place, if the insertions of the hamstrings offer unusual resistance, posterior displacement may ensue. When great resistance is anticipated, the hinges are placed slightly behind the center of motion of the knee joint; this position creates a forward thrust on the upper end of the tibia which tends to prevent subluxation and to correct an existing subluxation. However, even this last measure may fail to prevent posterior subluxation of the tibia during correction. When this occurs, surgical intervention followed by skeletal traction is indicated.

Correction of the deformity should proceed slowly, always within the tolerance of the patient. The author does not allow weight bearing until the knee deformity is corrected at least to 160°. If weight bearing is allowed on knees with flexion contractures greater than 20°, too much strain is imposed on the soft tissue structures of the hip and the knee. During this period, nonweight bearing exercises designed to strengthen the extensor apparatus are performed. This comprises quadriceps drill in the cast and straight leg raising against increasing loads. It must be remembered that the vastus medialis can be exercised when the knee is partially flexed if the exercises are performed against resistances. After the maximum amount of correction is achieved, the limb is protected by caliper braces. As recorded previously, knee braces tend to promote further muscle atrophy; hence this undesirable feature can be counteracted only by an intensive regimen of progressive muscle exercises. The surgeon

should strive to redevelop muscle power and volume in both the quadriceps and the flexors of the knee to such a level that the braces can be discarded within a few months without fear of recurrence of the contracture Now the muscular apparatus should be sufficient to stabilize the knee joint It may take 6 months or more of intensive work by the patient to attain this goal.

Recurrence of flexion contractures may be secondary to disturbances in the mechanics of joints proximal and distal to the knee Flexion deformities of the hip and pronounced weakness of the gastrocnemius muscle necessitate varying degrees of flexion of the knee during locomotion in order to meet gravitation stresses It becomes apparent that the aforementioned factors must be evaluated and corrected in order to preclude or minimize the tendency toward recrudescence of the deformity The range of motion attained by this method of correction is governed by many factors, chiefly the degree of destruction of the opposing articular surfaces in the femur, the tibia and the patellofemoral joint the amount of correction obtained and the status of the muscular apparatus particularly the quadriceps muscle

Contraindications to Correction by Turnbuckles. Correction by turnbuckles is not applicable in all cases of flexion deformities of the knee of arthrogenic origin The pertinent contraindications are (1) severe fixed deformities with posterior subluxation of the tibia (2) deformities of long standing in which irreversible changes have occurred in the hamstrings which will not stretch sufficiently to allow the center of motion during correction with a cast and turnbuckle to be maintained at the center of the joint (3) severe implication and contracture of the posterior capsule (4) pronounced intra-articular damage with fibrous and bony ankylosis (5) intra-articular mechanical obstructions to extension as hypertrophied fat pads (6) lesions of the skin and other soft tissues which preclude application of pressure and (7) active joint disease

The contraindication listed last (active joint disease) is not considered by some authorities as a substantial reason for prohibiting correction of flexion deformities of the knee joint. These workers contend that deformities should be corrected during the acute or the subacute phase of the inflammatory process before the contractures become fixed and irreversible tissue alterations occur They advocate correction of the deformities by manipulation under anesthesia in those cases which fail to respond to the method of repeated application of casts after a period of relaxation Some instances may require repeated manipulations The author has employed this principle in several cases of rheumatoid arthritis in the acute stage exhibiting flexion contractures of the knee. In all, correction was attained and maintained subsequently by plaster splints Although it is generally accepted that deformities should be corrected during the quiescent stage of the disease certain selected cases can be corrected during the acute stage with no increase in the intensity of the local process. As a matter of fact, in the aforementioned instances it was interesting to note that after muscle spasm was abolished by deep anesthesia very little force was needed to obtain the desired correction

The above method may also be utilized following open procedures to improve the amount of correction It is not to be employed in cases of posterior subluxation In long-standing cases stretching of the neurovascular structures in the popliteal fossa and the peroneal nerve as it winds around the head of the fibula always must be borne in mind, regardless of the methods employed to achieve correction. The peroneal nerve is particularly prone to injury any manifestations pointing to involvement of this nerve should be a danger signal to the surgeon warning him of impending trouble Protracted or permanent paralysis

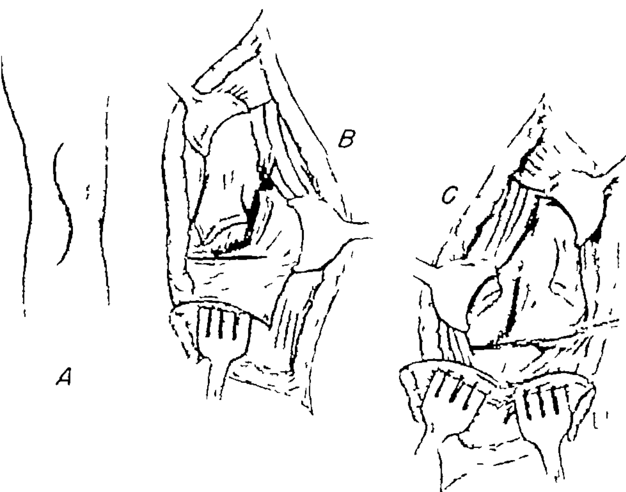


Fig. 361 (A) Incision for posterior capsulotomy (B) The lateral head of the gastrocnemius muscle the lateral one half of the posterior capsule and the proximal insertion of the posterior cruciate ligament are divided transversely (C) then the medial head of the gastrocnemius and the medial one half of the capsule are sectioned

is not an uncommon complication following correction of severe flexion contractures It may follow any method of correction but most often closed methods.

Operative Procedures. As recorded previously surgical intervention is reserved for cases in which conservative measures fail to correct the deformity also for cases in which posterior subluxation of the tibia occurs during turnbuckle correction or exists prior to any form of treatment and finally in cases of long standing with profound contractures of all the posterior structures particularly the posterior capsule Two operations to achieve correction are utilized frequently these are posterior capsulotomy and Wilson's posterior capsuloplasty

Posterior Capsulotomy (Fig. 361) Under a tourniquet a lazy S shaped incision 6 inches long is made in the center of the popliteal fossa After the skin the subcutaneous tissue and the superficial fascia are divided first the lateral and then the medial aspects of the posterior capsule are exposed After the deep fascia is identified in the mid line the overlying skin and the subcutaneous tissue are dissected free toward the outer side of the knee exposing the lateral aspect of the popliteal space where the deep fascia is split longitudinally Through this exposure the biceps tendon

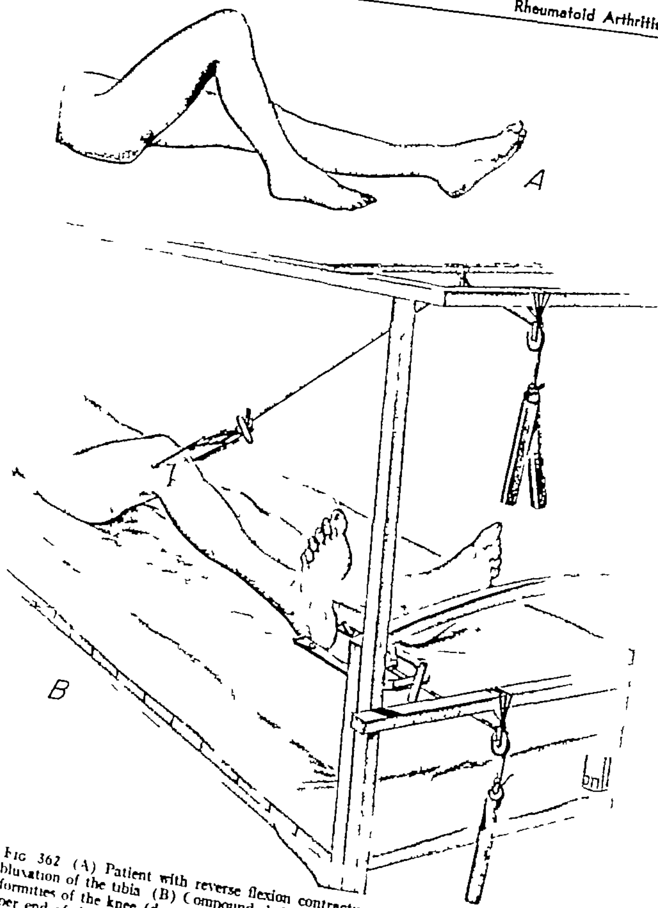


FIG 362 (A) Patient with reverse flexion contracture of the knee and posterior subluxation of the tibia (B) Compound skeletal traction employed to correct flexion deformities of the knee (described by O'Donoghue) Vertical traction is made in the upper end of the tibia and horizontal traction on the lower part of the leg



FIG 361 (A) Incision for posterior capsulotomy (B) The lateral head of the gastrocnemius muscle, the lateral one half of the posterior capsule and the proximal insertion of the posterior cruciate ligament are divided transversely (C) then the medial *head of the gastrocnemius and the medial one half of the capsule are sectioned.*

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B

Fig 362 (A) Patient with reverse flexion contracture of the knee and posterior subluxation of the tibia (B) Compound skeletal traction employed to correct flexion deformities of the knee (described by O Donoghue) Vertical traction is made in the upper end of the tibia, and horizontal traction on the lower part of the leg

and the common peroneal nerve are identified and displaced laterally, exposing the lateral head of origin of the gastrocnemius muscle Next, the neurovascular structures occupying a position in the middle of the popliteal fossa are isolated and retracted medially This is followed by transverse section of the lateral head of the gastrocnemius muscle the lateral half of the posterior capsule and the proximal attachment of the posterior cruciate ligament.

The next step in the operation is development of a line of cleavage between the subcutaneous tissue and the deep fascia on the medial aspect of the popliteal fossa By dividing the deep fascia on the medial side of the joint longitudinally the semimembranosus and the semitendinosus are exposed These structures are displaced medially, and the popliteal vessels and nerves are retracted laterally Next the medial head of the gastrocnemius and the remaining medial half of the capsule are divided transversely under vision Following *the last step in the procedure the* amount of extension possible in the knee joint is dependent upon the resistance offered by the hamstrings If these structures *are not fibrotic and shortened extension* can be accomplished by minimal force great force never must be employed and its use is condemned Contracture of the hamstrings and the iliotibial band may preclude correction of the deformity In this event the tendons of the biceps semimembranosus and semitendinosus are lengthened by a Z shaped tenotomy and the iliotibial band and the lateral intermuscular septum are divided transversely After completion of the operation the wound is closed in layers in the normal manner

If complete correction is accomplished by the above procedures the limb is immobilized in the position of full extension by a long leg plaster cast. Quadriceps drill and straight leg raising are started immediately After 2 weeks the cast is replaced by a caliper brace and protected weight bearing is commenced The subsequent postoperative management is similar to that described following turnbuckle correction of flexion contractures

Failure to obtain complete correction because of undue shortening of the neurovascular bundle can be overcome by the application of a long leg cast, hinges and turnbuckle as described previously In the event that posterior subluxation of the tibia is present this deformity can be corrected by the use of compound skeletal traction as described by O Donoghue (Fig. 362) Essentially, this comprises the application of skeletal traction to the upper end of the tibia and to the os calcis so that vertical traction is made on the proximal end of the tibia while at the same time linear traction is made on the leg Instead of Kirschner wires, the author employs threaded wires these do not slide back and forth in the osseous tunnels and therefore the possibility of infection is minimized A threaded wire is passed through the proximal end of *the crest of the tibia a tension bow is at*tached to the wire and vertical traction is achieved by suspension to an overhead bar The second wire is passed through the *os calcis this permits the application of* horizontal traction to the distal end of the leg. At the beginning of the treatment maximum traction is applied in the vertical direction and less in the horizontal as the deformity becomes less more pull is applied in the horizontal plane and less in the vertical The rapidity of correction always should be within the tolerance of the patient and the tissues As the end of the correction is reached the vertical traction becomes minimal or may be eliminated. This method is employed by O Donoghue to replace operative procedures the author finds it an excellent method to supplement operative procedures It is particularly useful in young individuals

Posterior Capsuloplasty (Wilson) (Fig 363) The operation is performed with a tourniquet placed high around the

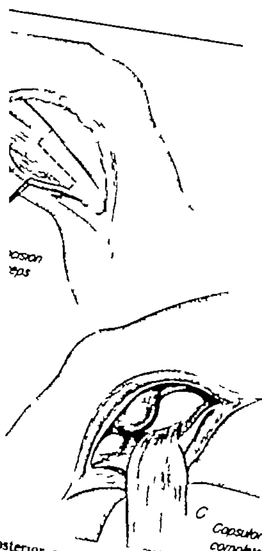


Fig 363 (A) Posterior capsuloplasty of P Wilson for flexion contracture of the knee joint through a medial and a lateral incision On the lateral side the peroneal nerve is displaced downward and a Z-shaped tenotomy is performed on the tendon of the biceps femoris (B) The lateral head of the gastrocnemius muscle is divided and the capsule and the periosteum are stripped off the bone for 3 inches proximally as far as the mid line (C) The same procedure is executed on the medial side of the joint.

thigh An incision 5 to 6 inches in length is made on the lateral aspect of the knee joint It begins immediately above the lateral condyle of the femur and extends distally to the head of the fibula After the iliotibial band is identified it is divided transversely approximately 2 inches above the joint line Next the biceps tendon is dissected free from the surrounding tissues for a distance of 4 inches proximal to its insertion into the head of the fibula. After the peroneal nerve is retracted downward and outward a Z-shaped tenotomy is per formed on the biceps femoris tendon This step allows visualization of the posterolat eral position of the capsule which is divided just behind the posterior margin of the lateral femoral condyle exposing the posterior compartment of the joint The capsule is stripped upward from the posterior surface of the femur then the capsular incision is projected upward over the lateral condyle of the femur exposing the attachment of origin of the lateral head of the gastrocnemius this structure is stripped off the bone and the capsule and the periosteum are stripped from the posterior aspect of the femur for a distance of 3 inches proximal to the joint line and as far as the mid line of the femur

A second incision is made on the medial aspect of the knee joint extending from the adductor tubercle to 1 cm below the joint line The posteromedial aspect of the capsule is exposed and incised, and the periosteum is stripped from the femur on the inner side as on the outer A wide piece of gauze is passed between the posterior surface of the femur and the capsuloperiosteal tissues now the posterior structures can be retracted readily With the knee flexed acutely and the posterior tissues displaced downward all tight capsular tissues in the intercondylar notch are mobilized by subperiosteal dissection The ends of the biceps tendon are approximated and sutured in the lengthened position Occasionally, the peroneal nerve becomes taut when the knee is extended this can be relieved by freeing the nerve in its course around the neck of the fibula to a point beyond the neck The wounds are closed in layers in the usual manner Postoperative management is the same as that described following posterior capsulotomy If correction of bilateral contractures is contemplated the operation should be performed on one knee at a time

Arthroplasty of the Knee Joint in Chronic Arthritis (Kuhns and Potter) As recorded previously, McKeever and Kuhns and Potter have used nylon as an interposition membrane in arthroplasties of the knee joint in cases of chronic arthritis A single ankylosis of the knee joint in the position of extension is not a serious disability However such situations are rarely observed in patients afflicted with rheumatoid arthritis In these cases multiple ankyloses including the knees may be encountered such patients would be benefited greatly by mobilization of one knee joint Many failures have been recorded following arthroplasties performed in chronic arthritis when fascia lata was used as the interposition membrane The factors are (1) all the soft tissues at the knee joint are implicated in the pathologic process (2) the residual deformities usually are encountered in cases of long standing the long period of dysfunction and inactivity results in profound demineralization of bones atrophy of the muscular apparatus and weakness and atrophy of the ligamentous structures and fasciae and (3) there is similar involvement of the fascia lata which loses its strength and becomes friable. According to Kuhns and Potter when used as an interposition membrane in arthroplasties of the knee joint it rapidly undergoes deterioration enhancing the formation of intra articular fibrous adhesions Nylon is a suitable material for interposition between the reshaped articular surfaces of the knee joint it gives rise to no tissue response it is thermolabile and resistant to chemicals and moisture, instances of hypersensitivity to nylon are exceedingly rare The substance has some very durable properties it is tough and moderately elastic. It is manufactured in strips 12 inches long and 5/100 inch in thickness it must be sterilized chemically the aforementioned workers recommend sterilization by immersion of the material in a 1 1 000 solution of mercuric chloride for 12 hours. Before it is used, it is placed in a solution of cold normal saline for 1 hour

A tourniquet is not used bleeding is controlled with the electrocautery large vessels are ligated. The knee joint is exposed by a long medial parapatellar incision (Fig 364 A) In severe cases the different layers of the soft tissues may be adherent to one another and also to the bone invariably the patella is fused to the anterior surface of the femur (Fig 364 B C) With a thin blade osteotome the patella is freed from the femur and then displaced laterally exposing the anterior aspect of the joint The capsule is usually adherent to the lateral surfaces of the femoral condyles It is freed by sharp dissection taking care to preserve the tibial and the fibular collateral ligaments Next the intra articular ligaments and the menisci are excised these usually exhibit advanced degeneration. The femur and the

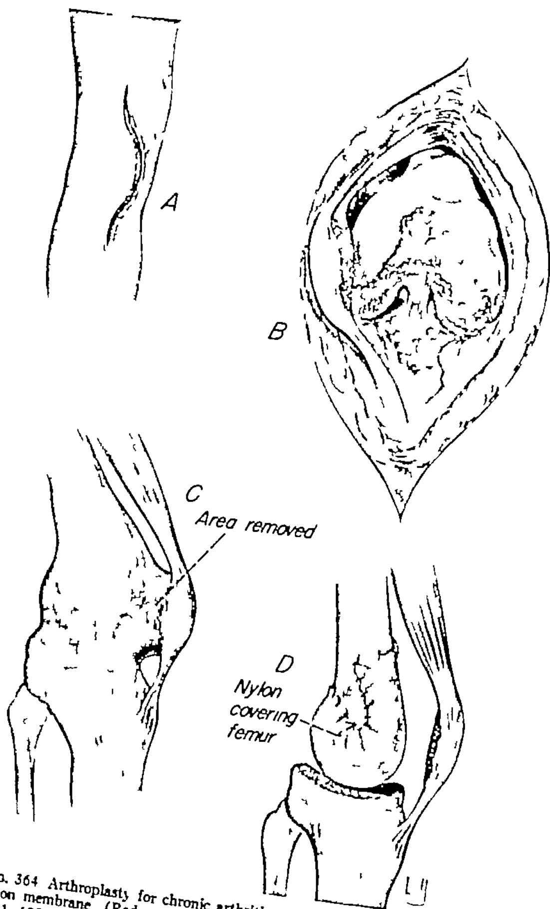


FIG. 364 Arthroplasty for chronic arthritis, employing nylon as the inter position membrane (Redrawn from Kuhns, et al. Surg., Gynec. & Obst. 91 351 1950)

tibia are separated with an osteotome the line of separation usually coincides with the old joint space. Flexion of the knee brings into view the posterior portions of the femoral condyles and the tibial plateaus

With a thin blade osteotome the distal end of the femur is remodeled from side to side *into a rounded wedge and a shallow groove* is made in the superior surface of the tibia *to receive the reshaped opposing surface of* the femur Approximately 1 inch of the joint is resected this permits unobstructed motion between the femur and the tibia With a rasp all roughened areas are made smooth so that the femur moves smoothly over the articular surface Next the bed for the patella is made by deepening the inter condylar notch The patella is shaved thin and its articular surface is made smooth this structure should not be sacrificed by *excision*

The bone ends are now ready to receive the interposition membrane A sterilized strip of nylon is attached first to the oblique popliteal ligament and posterior portion of the capsule by interrupted fine nylon or silk sutures Then the nylon strip is stitched to the periosteal tissue at the sides of the femoral condyles and finally pleated to fit snugly over the newly shaped bone end The strip should be long enough to cover *the supracondylar portion of the femur* hence precluding the formation of adhesions in this region (Fig 364 D) After all bleed ing points are controlled the wound is closed in layers with sutures of fine silk or nylon A compression dressing is applied extend ing from the ankle to the groin no cast or plaster splint is deemed necessary Length ening of the rectus femoris tendon is not required If resection of the opposing bone surfaces fails to provide at least 90° of flex ion *the attachments of the vasti muscle to* the rectus femoris muscle and the patella are sectioned and the scarred distal portion of the vastus intermedius is dissected free and excised according to the method of T C Thompson This procedure permits the de sired range of flexion

At the termination of the operation the leg is elevated on pillows for 48 hours and supportive measures are instituted such as the administration of fluids and blood Antibiotic medication is also given. The wound is not disturbed for 5 or 6 days at the end of this period the wound is re dressed *and* active exercises for flexor and extensor muscles are commenced antigrav ity *exercises are started as soon as the* wound is healed, and weight bearing is al lowed in a bivalved plaster cylinder at the end of the third week Restoration of muscle power volume and control is achieved by the methods described on page 260 Severe muscle atrophy and bone demineralization may retard weight bearing for several months usually a caliper brace is required for at least 4 months as a rule, maximum restoration of muscle function is achieved *in 9 to 12 months In most instances good* painless function is obtained in 6 months.

Kuhns and Potter point out (1) that arthroplasty on a knee in flexion is not diffi cult if the articular ends of the bones are resected widely and the capsule is freed from the posterior margins of the femoral condyles (2) the gliding surface under the quadriceps tendon must be restored by a covering of nylon in order to prevent the formation of adhesions, (3) in cases of *multiple ankyloses arthroplasty* is justifia ble in cases with marked articular damage with intra-articular fibrous adhesions and limited motion (4) bony ankylosis is not a prerequisite for the procedure (5) in patients who retained some motion the operation was technically less difficult (6) if marked hypertrophy of *the* synovial membrane was present a synovectomy was *indicated at operation* (7) usually the operation is not done in patients over 60 *years of age* (8) the operation has a wider application in cases of osteoarthritis with profound degenerative alterations in the articular surfaces. They list the following contraindications (1) the presence of an active inflammatory process the process should be quiescent at least one year before

arthroplasty is performed, (2) debilitated patients, (3) in children with rheumatoid arthritis no arthroplasty of the knee joint should be contemplated until the epiphyses are closed

SYNOVECTOMY In spite of the good results recorded by some, many workers have been disappointed with the results of débridement operations in knee joints crippled by rheumatoid arthritis This has not been the experience of the author therefore, this procedure alone is recommended for cases of rheumatoid arthritis, particularly when all evidence of acute inflammation has subsided The procedure does relieve pain and removes hyperplastic tissue which acts as a mechanical block to free motion and interferes with nutrition of the articular cartilage

DEGENERATIVE ARTHRITIS

The synonyms for this entity are listed in the classification found at the beginning of this chapter As in rheumatoid arthritis, so in degenerative arthritis, the terminology is confusing because the etiologic factors are not known hence, investigators have employed numerous and various criteria as the basis for their designations. Most of the terms employed endeavor to indicate the osseous and cartilaginous alterations encountered in this malady as well as the roentgenographic features also, they emphasize the pertinent characteristic clinical feature namely the tendency for the lesion to be manifest in individuals past middle life Degenerative arthritis has been recognized and studied in man and animals by numerous observers some of which date back many centuries The lesions in man are comparable with the abnormalities noted in the joints of old animals which are believed to be a physiologic response to wear tear and aging It is the belief of some workers that these regressive changes are influenced in a large measure by metabolic disturbances which are governed by alterations in the normal function of glands of internal secretion

ETIOLOGY

As recorded previously the etiology of degenerative arthritis is not established however clinical and scientific studies disclose that certain factors play a role in the pathogenesis of the disorder

Constitutional Factor It is recognized generally that changes in the articular cartilage of joints which are consistent with degenerative arthritis may appear in some individuals early whereas in others they appear late in life and may be only minimal in severity Also, the malady is encountered more frequently in the sthenic constitutional type than in asthenic individuals These observations lead one to conclude that the cartilage of one individual is endowed with inherent properties which can withstand wear, tear and aging without undergoing pronounced degenerative alterations whereas the cartilage of other individuals, when subjected to the same stresses incurred during normal function is unable to cope with these forces and deteriorates rapidly

Trauma. It is acknowledged generally that trauma in some form is active in initiating the changes that culminate in degenerative arthritis The articular cartilage may be traumatized by numerous forms of mechanical insults for practical purposes these can be divided into two groups Trauma may be the result of physiologic wear and tear associated with normal joint function such as in walking standing running or excessive use of the articulation in certain occupations or athletic endeavors Essentially, this trauma comprises microtraumas, the accumulated effect of which is responsible for the regressive changes in the articular cartilage It has been demonstrated that standing and walking have no effect on the osseous elements of weight bearing joints but that the cartilage is compressed Compression of this nature interrupts completely the avenues of circulation

to the cartilage cells During walking this brief interference in the supply of nutrient materials to cartilage has no deleterious influence however, the same compression forces acting for long periods, such as in occupations requiring prolonged standing result in the development of degenerative changes which early in the disease comprise fibrillation softening and loss of elasticity in the superficial layers of the cartilage Obesity tends to intensify the microtraumas of normal joint function

On the other hand trauma may be solitary and severe particularly if it produces one or more fractures of the articular surface. Such injuries may cause local areas of degeneration of articular cartilage which is avascular tissue of which powers of regeneration are for practical purposes insignificant In addition the local changes may be responsible for the development of incongruous articular surfaces which in turn magnify many times the intensity of microtraumas of everyday life Other factors capable of inflicting traumas in varying degrees of severity to the cartilage of bone ends are poor posture and faulty weight bearing. All orthopedic surgeons are familiar with the joint changes that accompany genu varum and genu valgum Disturbance of the normal mechanics in these joints invariably produces degenerative alterations earlier than would be expected in joints without deformity The same is true of changes in the normal alignment of hips ankles spine and feet The static deviations subject certain areas of the affected joints to increased compression which in turn deprives the cartilage cells of a normal exchange of joint fluid This disturbance in circulation deprives the amount of available oxygen and favors the accumulation of noxious agents All these factors enhance the development of degenerative abnormalities in the articular cartilage

Senescence. Although the disease is observed occasionally in the third decade it is encountered most often after middle life particularly in the fifth, sixth and the seventh decades There is a progressive increase in the intensity of the degenerative alterations with each successive decade These observations were noted by Bennett Waine and Bauer The same observations were recorded in the author s study of degenerative lesions of the shoulder joint in various decades however changes in non weight bearing joints are less severe than those encountered in weight bearing joints All gradations of degenerative arthritis are encountered in individuals of the same age period an individual in the fifth decade may exhibit advanced alterations in the knee joints while another individual in the seventh decade may exhibit only minimal changes However, when an attempt is made to establish a norm for each decennium it becomes apparent that the increase in gradient of the degenerative abnormalities is progressive in each successive decade. Study of the numerous causative agents that may initiate degenerative arthritis makes it apparent that regardless of what other agents may be responsible for the disease aging plays a very significant role.

Infection. Infection as a causative agent in degenerative arthritis has been a topic of considerable controversy However it is generally accepted at the present time that infection plays no role in the pathologic processes of this disorder It must be admitted that occasionally an active focus may be coexistent with accentuation of the local manifestations however it is difficult to conceive that such a focus is the causative agent responsible for a degenerative process of long standing

Vascular Disorders. It is true that degenerative arthritis is more apt to develop in people who frequently are afflicted by vascular disorders such as degenerative vascular disease hypertension and arteriosclerosis (sthenic type) Aseptic necrosis of bone has been compared with massive myocardial infraction In spite of this observation, there is no conclusive evidence

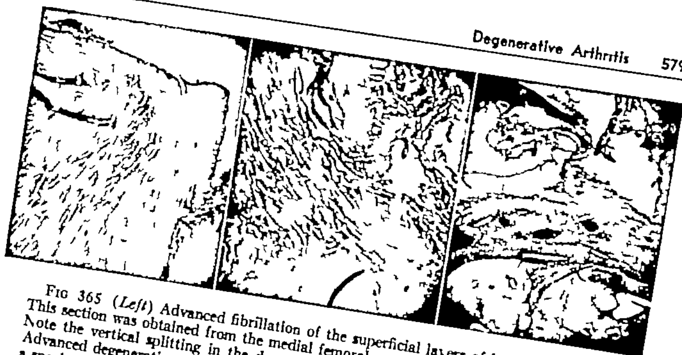


FIG 365 (*Left*) Advanced fibrillation of the superficial layers of hyaline cartilage. This section was obtained from the medial femoral condyle of a patient 52 years old Note the vertical splitting in the deep layers (Photomicrograph × 100) (*Center*) Advanced degenerative alterations of hyaline cartilage in the medial tibial plateau in a specimen of the seventh decade Observe the areas of fibroblastic activity, the metaplasia of hyaline cartilage and the defective fibrocartilage Also note the nest of cartilage cells scattered throughout the deteriorated articular cartilage. (Photomicrograph × 100) (*Right*) Different area of specimen B The cartilage is worn away completely The articular cortex is markedly thickened and dense The narrowed marrow spaces contain proliferating connective tissue which tends to project to the surface and cover the exposed subchondral bone. (Photomicrograph × 200)

on hand which points to disturbances in the vascular system of bone as the prime factors responsible for the disease Local areas of the bone ends in a joint may undergo aseptic necrosis as is often seen in the head of the femur following injury or fracture of the femoral neck These produce incongruities of the articular surfaces which lay the basis for development of degenerative arthritis It must be understood that aseptic necrosis of the bone per se was not the etiologic factor in these instances

Endocrine Deficiencies. The frequent occurrence of generalized degenerative arthritis in women during the climacteric period has been a strong incentive to incriminate dysfunction of the endocrine glands as the prime etiologic factors In spite of this coincidence convincing evidence establishing disturbances of endocrine function as causative agents is lacking

Metabolic Disturbances and Vitamin Deficiencies Metabolic factors and vitamin deficiencies have been accredited from time to time as possible etiologic factors of degenerative arthritis However there is no evidence to substantiate these premises

Pathology and Pathogenesis

Numerous investigations concerned with the pathogenesis and the pathology of degenerative arthritis have been recorded in the literature The studies of Nichols and Richardson and Bennett Waine and Bauer are monumental pieces of work and have contributed much to our knowledge of chronic arthritis Some of the other investigators that must be mentioned are Virchow, Volkmann Hunter, Weichselbaum Pommer Heine, the Garrods Charcot Heberden Fisher Kanggs Schmoral Goldthwait, Allison and Ghormley, Ely, Keefer Freund Erdheim Key and Adams

The earliest changes in degenerative arthritis implicate the articular cartilage Macroscopically the first alteration noted

s loss of elasticity The resilient, glisten ng bluish white cartilage observed in in ancy becomes opaque, yellowish firm and ompact These changes are more discerni le in areas subjected to great pressure and ompression the normal shock absorbing eatures of the hyaline cartilage is now lost oon the cartilage becomes soft, and fibril ation of its superficial layers ensues, giv ng the structure a velvetlike or papillary ppearance With increase in gradient of hese changes the cartilage exhibits small rregular scalloped, ulcerated areas In ome areas the articular cartilage is com letely worn away, exposing the subchon ral bone which becomes thickened and ompact and assumes a highly polished sur ace In the early stages the superficial ayers of cartilage lose their affinity for tain *it is believed that the fibrillation* oted above is the result, in part, of de eneration of the binding substance of the natrix of the cartilage, permitting the su erficial bundles of collagen to be erased nd the deep radial bundles to separate Fig 365)

According to some workers the forma on of Weichselbaum s lacunae is indicative f early degenerative alterations in the yaline cartilage Defects noted in the car lage are believed to be the result of reso- tion of the defective matrix by cartilage ells which have assumed chondroblastic unctions The process has been designated "lacunar resorption" The lacunae are xpanded and may coalesce to form larger paces which contain primitive connective ssue Later degeneration of the cartilage ells may occur and with rupture of some the more superficial lacunae of Weich lbaum the surface assumes a pitted ap- earance Cartilage cells adjacent to the brillated matrix also exhibit evidence of egeneration Below the tangential stratum ey are fewer in number they stain abnor ally and the normal pattern of the cells distinct layers is lost In the transitional d calcified zones of the cartilage the number of the cells is reduced, and the cells are arranged in groups varying in size

Small surface areas of erosion coalesce so that large portions of subchondral bone are exposed this is particularly noted in the center of the femoral condyles the tibial plateaus and on the medial and the lateral facets of the patella, these areas are subjected to greater friction during joint motion than the remaining portions of the articular surfaces of the femur the tibia and the patella

Traut points out that during joint motion two forces act on the articular cartilage— a perpendicular and a diagonal or shearing force These forces play an important role in supplying cartilage cells with nutrient materials found in the synovial fluid During normal joint motion the pressure and the shearing forces are applied *intermit* tently this mechanism pumps nutrient fluid to the cartilage It becomes apparent that any defect in this mechanism jeopar dizes the existence of the cartilage As noted previously degenerative alterations in the cartilage cause the structure to lose its re siliency also changes in the hyaline-bind *ing substance (chondroitin-sulfate-protein)* are responsible for fibrillation of the car tilage incident to abnormal mobility of the collagenous fibrils

When the bone ends have lost the protec tion provided by normal hyaline cartilage the aforementioned pressure and shearing forces act directly on the subchondral bone initiating in the spongiosa proliferative and hypertrophic responses The pathologic re sponses differ in various areas of the same joint In general the calcified zone of the cartilage exhibits increased thickness most probably due to increased amounts of cal cium deposition in the hyaline zone In such instances Bennett et al noted that spotty ossification in the subchondral plate ren- dered this structure markedly *irregular* they proposed that the abnormal calcifica tion stimulated the ossification process As a rule little alteration is discernible in the

subchondral bone except in cases showing advanced changes in the cartilage Frequently, deep erosions of cartilage are associated with increased vascularity of the marrow spaces, showing fibrocytic and endosteal proliferation."

Areas denuded completely of cartilage invariably disclose pronounced alterations in the subchondral bone Areas subjected to pressure forces, such as weight bearing surfaces, exhibit marked increase in density and sclerosis occasionally the bone is eburnated Immediately adjacent to these, other areas of decreased density are encountered Microscopic study of the affected tissues reveals that the subchondral marrow spaces contain a rich, vascular, granulation tissue, the osteoblasts arranged along the adjacent trabeculae lay down abundant osteoid tissue, the process parallels enchondral ossification Concomitantly osteoclasts in the vicinity of the osteoid matrix resorb channels in the adjacent trabecular bone It is obvious that this process attempts to readjust the trabecular pattern of the subchondral bone In denuded areas active trabecular readjustment is a conspicuous feature, this always is associated with diminution in the sizes of the marrow spaces and increased density of the bone ends Pommer was of the opinion that the degree of subchondral condensation was governed by the intensity of weight bearing stimuli in joints of which the articular cartilage was defective or worn away completely With this premise many investigators agree

A constant feature of degenerative arthritis is peripheral proliferations comprising bone and cartilage These peripheral outgrowths have been given many designations some of them are spurs or marginal osteophytes on the fingers and the toes they are called Heberden s nodes and marginal exostoses Many theories of origin have been proposed Nichols and Richardson Beneke and others maintained that these were physiologic responses of a compensatory mechanism in an attempt to improve the stability of the joint by increasing the dimensions of its articulating surfaces. On the other hand, some workers expressed the view that the marginal excrescences were the result of peripheral displacement associated with compression of defective cartilage (Knaggs, Parker et al) Bennett and his co-workers point out that as the result of loss of elasticity in degenerating cartilage, weight-bearing imposes additional stress in the form of sustained traction on the peripheral joint margins. This force tends to initiate hyperplasia and hypertrophy in the marginal tissues The aforementioned investigators were of the opinion that marginal proliferations are not secondary features, since they were able to demonstrate the lesions in joints with no subchondral alterations and only minimal changes in the articular cartilage They proposed the theory that the connective tissue at the border zone between the articular cartilage and the synovial membrane is more primitive than the cartilage or the synovialis and that this less-specialized tissue is unusually vascular, even in adult life Furthermore, it is capable of marked proliferation and reparative powers. Pommer and Wehner proposed still another mode of genesis. They claimed that the peripheral outgrowths were the result of endochondral ossification in the subchondral bone the newly formed tissue advanced into the deteriorated cartilage Growth of the newly formed tissue is resisted in all directions, except at the periphery of the joint surfaces this provides an explanation for the predominately marginal process encountered in advanced cases of degenerative arthritis Axhausen attributed the formation of these excrescences to metaplasia of proliferating synovialis and also to periosteal proliferation with subsequent osteophytic formation

Subchondral cysts are associated lesions of degenerative arthritis, they vary in size and configuration and are more predomi



FIG 366 Bilateral degenerative arthritis in a woman 58 years old The articular surfaces of the femurs are irregular particularly those of the medial femoral condyles. The medial joint spaces are narrowed. Observe the lipping of the poles of the patellae and on the anterior articular surface of the femurs. New bone formation is also noted on the posterior femoral condyles. Fracture of the excrescences may give rise to loose bodies

nant in joints exhibiting advanced alterations Their mode of genesis is not clear and hence their origin is highly debated. Some believe they are encapsulated hemorrhages in the subchondral bone others claim they are produced by osteoclastic activity It is interesting to note that they are generally observed in areas of increased density and bony sclerosis This observation has led to the conclusion that the cysts are products of osteoclasia induced by excessive mechanical stresses Luck pointed out that mechanical stresses within certain limits favor osteoblastic processes whereas greater stresses induce osteoclastic activity localization of this phenomenon results in formation of cysts

Capsular Alterations. Changes in the synovialis and the fibrous capsule of the joint are not primary manifestations of degenerative arthritis and are not characteristic. As will be shown subsequently knee joints exhibiting severe abnormalities of the articular cartilage may disclose only minimal changes in the capsular tissues Generally with advancing age the severity of changes in the capsule increases in gradient Essentially the changes comprise hyperplasia and villous formation of the synovialis the reaction is more pronounced at the joint edges The synovial membrane may be thrown into folds and fringes Villi vary extremely in number size and shape they may appear as fine fingerlike projections or as branching, papillary or even polypoid structures or grapelike clusters Metaplasia of tissues may occur producing osteoid tissue or even bone The tissues may be infiltrated with fat, producing lipoma arborescens Mechanical insults to these tissues may cause hemorrhage into the joint resulting in deposition of varying amounts of hemosiderin in the synovialis. Free bodies in the joint arising from the synovial membrane the articular cartilage or by detachment of peripheral excrescences may inflict injury to the synovialis giving rise to traumatic synovitis with effusion which in turn produces hydrops of the intra-articular soft tissue

With progression of the aforementioned alterations in the hyaline cartilage the subchondral bone and the capsule the normal configuration of the joint is altered greatly (Figs 366 and 367) In advanced cases varying degrees of subluxation may

ensue the capsular tissues are thickened and the pericapsular tissues are distended and weakened these soft tissue changes may appear not unlike those encountered in rheumatoid arthritis however, one must remember that these two entities are in no way related insofar as etiologic agents are concerned Although the joint changes are responsible for varying amounts of dysfunction, deformity and restricted motion, true fibrous or bony ankylosis does not occur in this disease this is a distinctive feature of degenerative arthritis

Loose Bodies Associated With Degenerative Arthritis

Frequently loose bodies are encountered in joints affected by degenerative arthritis, these may be single or multiple and may be the products of different modes of genesis They may arise by metaplasia of cells comprising the synovial membrane (osteochondromatosis) or by severance o base of a marginal osteophyte or b placement into the joint of loose frag of articular cartilage. As noted previ regardless of the origin of the free bo behavior and fate is the same in a stances Those arising from the sy lining may remain attached to their formation, may become pedunculat may be displaced into the joint cavity bodies having an osseous nucleus nutrient materials from the synovial which are sufficient to sustain the ficial cartilage layers of the body and permit proliferation of the cartilage c that the body shows progressive incre size On the other hand, the central o portion of the body undergoes necros remains in an inert state Microscopi tions of free bodies exhibit a pattern la uniformity of structural formation, prising strata of noncalcified car



Fig 367 Far-advanced degenerative arthritis of the left knee joint in a woman 62 years old. Observe the marked irregularity of the articular surfaces the subchondral sclerosis the loose body in the anterior aspect of the joint the retropatellar arthritis and the advanced marginal lipping of the inner tibial condyle.



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Fig 367 Far advanced degenerative arthritis of the left knee joint in a woman 62 years old. Observe the marked irregularity of the articular surfaces the subchondral sclerosis the loose body in the anterior aspect of the joint, the retropatellar arthritis and the advanced marginal lipping of the inner tibial condyle.

throughout which layers of irregularly ossified cartilage are interspersed Also, irregular areas of defective bone may be demonstrable through the layers of cartilage If the body regains attachment to the synovialis it may be perforated by blood vessels which by creeping substitution transform *the dead to living bone*

Clinical Features

The disease rarely affects persons under 40 years of age however, isolated cases have been recorded in patients in the third decade The incidence in men and women is approximately the same The joints most commonly implicated are those most vulnerable to trauma the weight bearing joints the terminal interphalangeal joints the spine the hips the knees and the ankles are most frequently involved Nodules (Heberden s nodes) observed in the terminal phalanges in elderly people especially women are manifestations of degenerative arthritis Of the weight bearing joints the knees are most often implicated

Although the disorder frequently appears as a mono-articular lesion several joints in the same individual may be involved Bilateral involvement of the knees the hips and the ankles is not an infrequent occurrence When the malady involves the fingers usually most or all of the terminal interphalangeal joints are affected

Comprehension of the pathology observed in degenerative arthritis of the knee joint permits one to evaluate adequately the significance of the signs and symptoms noted in the clinical course of the disease In general degenerative changes associated with senescence and not aggravated by major traumas develop slowly but progressively from decade to decade It is interesting to note the extensive changes that are encountered in the late-age periods of life that are compatible with good function and symptoms of minimal intensity Lesions initiated by severe violent traumas usually give rise to symptoms earlier than those resulting from microtraumas incident to normal joint motion, but even these may not produce severe clinical manifestations for a period of several years In the knee joint derangements of the ligamentous apparatus the extensor mechanism or repeated episodes of synovitis associated with torn menisci or free bodies are frequently the etiologic factors responsible for repeated traumas which culminate in varying degrees of degenerative arthritis producing marked dysfunction and pain

In many instances even in the presence of advanced alterations the only clinical evidence of the disorder is creaking or snapping sensations in the knee joints With the quadriceps relaxed one can elicit crepitus in the patellofemoral joint by moving the patella from side to side while pressing it against the anterior articular surface of the femur Frequently particularly in obese women soft swellings are demonstrable on either side of the patellar tendon these consist of pads of fatty tissue which are often painful and may be the chief complaint of the patient

Characteristic of the disease is pain and muscle spasm precipitated by excessive exertion of the joint generally, these symptoms are relieved by rest Most joints exhibit a certain level of painless function if this level is exceeded, symptoms of varying severity ensue This observation is significant in formulating a plan of therapy since, if the tolerance of the affected joint is not exceeded pain and dysfunction are maintained at a minimum It was noted previously that fusion of the joint such as occurs in rheumatoid arthritis does not occur in degenerative arthritis however changes in the configuration of the articular surfaces spasm and contracture of muscles and fibrosis of capsule and ligaments may seriously impede the normal arcs of motion so that restriction of motion to some degree is a constant concomitant finding in the advanced cases Palpation of the peripheries of the articular surfaces may reveal long



Fig 368 (*Left*) Bilateral degenerative arthritis in a female 64 years old. A synovectomy has been performed on the right knee. Observe the pronounced thickening of the capsular tissues. No other joints were involved in this patient. In this case the soft tissue alterations resemble those encountered in rheumatoid arthritis, whereas the osseous and the cartilaginous changes are typical of degenerative arthritis. Occasionally this variety is referred to as a mixed form of arthritis however, no element consistent with rheumatoid arthritis was present in this patient. (*Right*) Thickened hyperplastic, edematous, synovial tissue removed from the right knee of patient depicted on the left.

projections, particularly at the poles of the patella and at the upper articular margins of the tibia (Figs. 366 and 367)

Relaxation of the capsular and supportive structures renders the articulation vulnerable to sprains incident to instability of the joint Occasionally, the degree of relaxation is extensive enough to allow varying degrees of subluxation of the articular surfaces In advanced cases the associated chronic synovitis may be the source of swelling synovial effusion and pain (Fig 368) Pronounced hyperplasia of the capsular tissue and intra articular fat pads may cause some restriction of motion and also give rise to symptoms of internal derangements of the joint when tabs of tissues are trapped between the opposing joint surfaces

A pertinent clinical characteristic is the absence of systemic manifestations in patients with degenerative arthritis It was pointed out previously that most of the individuals affected belong to the sthenic type and often are obese The sedimentation rate and most other laboratory tests are within normal range. In some instances, the blood cholesterol may be elevated and the basal metabolism rate low the creatin secretion in urine may be increased to a marked degree

Roentgenographic Findings

In the early stages of development of degenerative arthritis of the knee joint the roentgenograms may reveal no significant findings because the pathologic process is confined to the superficial layers of the articular cartilage This is particularly true in early lesions implicating the patellofemoral joint In spite of the fact that crepitus can be elicited on physical examination and felt and frequently heard by the patient, roent*genograms fail to depict any abnormalities* in the patellofemoral joint With further progression of the disease some spurring may be demonstrable on the tibial spines, at the poles of the patella and at the tibial *margins Also the joint space may be* slightly more narrow than that on the unaffected side and some increase in density may be discernible in the subchondral region of the articular surfaces particularly *at the sites of maximum weight bearing* Advanced lesions are recognized readily by roentgenographic study The joint space is narrowed and the articular surfaces may be irregular Spurring and lipping of the joint *margins are prominent features and margi*nal ecchondroses and osteophytes and subchondral cysts are readily demonstrable (Fig 367) In addition some cases may exhibit varying degrees of subluxation of *the articular surfaces and marked thick*ening of the capsular tissues Occasionally one or more loose bodies are seen in the intercondylar notch or in one of the joint recesses In elderly individuals the disease may be complicated by rarefaction of the shafts of the bone ends a feature indicating senile osteoporosis

Conservative Management

General Measures It is generally accepted that pathologic alterations in degenerative arthritis once established are irreversible However much can be achieved toward relieving the patient of pain and improving function This can be achieved by removing mechanical factors which tend to inflict repeated traumas to the joint, by restoring *normal alignment* in order to remove all abnormal stresses from the articular surfaces and supportive structures of the joint, by restoring to normal the soft-tissue elements particularly the power and the *tone of the quadriceps muscle* and finally by improving the general health of the patient by correcting those factors which may contribute to enhancement of the arthritic process such as overweight poor posture *and strenuous occupations*

As pointed out many times in this text it is mandatory that all forms of internal derangements of the knee joint be eliminated in order to preclude development of degenerative arthritis In those cases in which the disease is already established removal of torn menisci or loose bodies and restoration of normal stability of the joint by improving quadriceps power are essential prerequisites to prevent progression of the pathologic changes Many cases of degenerative arthritis of the knee joint are improved greatly by these measures Relaxation and loss of power of the extensor mechanism are relatively frequent concomitant findings in advanced cases Now the stabilizing effect and the protective influence of a normal quadriceps apparatus are lost and the capsular and the ligamentous apparatus are subjected to microtraumas incident to normal function also these structures are made more vulnerable to abnormal stresses. All these factors contribute to joint injury and progression of the disease It becomes obvious that the importance of restoring the quadriceps muscle to maximum power cannot be overemphasized

All abnormal body mechanisms which in any way may subject the affected knee joints to harmful stresses should be improved This includes unfavorable postural habits pronated feet flexion deformities of the hips and any abnormalities of the involved knee joint Particular attention should be given to the correction of flexion deformities of the affected joint Even minor

flexion contractures of the knee joint place abnormal, deleterious stresses on its supportive structures and enhance development of degenerative changes, such flexion abnormalities must be corrected The knee functions at its maximum efficiency without strain only when full extension is achieved readily

It was recorded previously that rest is an essential factor in the regimen of therapy The patient must be encouraged to perform nonweight bearing, quadriceps muscle exercises against progressively increasing loads but the tolerance of the muscles never must be exceeded The same principle is applicable to all other forms of activity if the patient s occupation or work habits are considered as sources of repeated traumas to the joint they must be changed or modified Obesity, particularly in women is a common contributory factor especially if it is associated with increased deviation of the knee joints although frequently difficult, measures must be taken to eliminate this detrimental influence wholly or in part. Except in the cases of gout, no special diet is indicated for the average individual affected with degenerative arthritis In general, the problem is the quantity rather than the quality of foods ingested Of course, unbalanced diets too rich in carbohydrate foods should be changed to diets balanced in all the essential foods, including an adequate intake of vitamins. Thyroid in cases showing evidence of deficiency may be given with advantage, it must be administered under constant medical supervision. Some workers believe that some improvement is observed occasionally in patients with menopausal symptoms when estrogens are prescribed Patients not responding to the female hormones may be given testosterone evidences of excessive growth of hair indicates that the dose must be reduced or the hormone discontinued In the author's experience estrogens or androgens have not materially affected the clinical manifestations of degenerative arthritis.

Local Measures Radiant heat and massage applied to the muscles above and below the knee joint are beneficial also hot fomentations tend to relieve stiffness and give comfort Daily underwater massage, such as that provided by the whirlpool bath, should be administered whenever possible, this is an excellent form of therapy to increase local circulation, relieve stiffness and improve muscle tone Exercises in a tub of heated water (92° F) are beneficial

Within the past year the author has instilled Hydrocortone (1 cc.) into the joint cavities of individuals with degenerative arthritis The relief obtained in many individuals is dramatic, whereas prior to the injection of the substance severe pain, swelling and pronounced dysfunction were outstanding features In some knee joints following the instillation pronounced improvement was discernible to the point that the disease was tolerable and the patient's usefulness enhanced For the first 3 or 4 doses it is given at weekly intervals the next 3 or 4 doses are given every second or third week depending on the rapidity with which distressing symptoms return In advanced cases most individuals are maintained on a dose given every 3 or 4 weeks The author has not encountered any unfavorable sequelae following local administration of Hydrocortone however, such complications have been recorded It must be remembered that this medication is not a substitute for all the other orthodox methods of therapy discussed previously So far it should be considered as only another therapeutic aid in the physician's armamentarium

Medications. The only drugs of any value are those capable of relieving the patient's pain during acute exacerbations of the disease Sodium salicylate (5 gr) or aspirin given with some antiacid as aluminum hydroxide-magnesium trisilicate gels (1 dram) suffices to provide sufficient relief in most cases. It may be taken as frequently as the pain dictates. Occasionally, aspirin (5 or 10

gr) is combined with codeine (½ gr) to give the desired effect More powerful drugs are rarely indicated

Surgical Measures

If amelioration of symptoms and improvement of function are not attained by conservative measures one may resort to certain surgical procedures Among those which have been accepted as worthy of trial are patellectomy débridement of the joint as described by Magnuson, arthrodesis and arthroplasty

Patellectomy and Chondrectomy In cases of severe retropatellar arthritis some authorities advocate patellectomy with good results In the opinion of the author this procedure should be reserved for cases of long standing with severe degenerative arthritis and with subluxation or dislocation of the patella in which it is technically impossible to restore a remodeled patella to its normal anatomic position on the anterior surface of the femur and stabilize it in this position during knee function The patella enhances the efficiency of the quadriceps apparatus and in its absence the quadriceps works at a definite mechanical disadvantage If the articular surface is involved sufficiently to deem surgical intervention justifiable complete chondrectomy and remodeling of the patella are preferable to excision The technic of patellectomy is described on page 227 that of chondrectomy on pages 246 to 248 In some cases of subluxated or dislocated patellae if it is possible to remodel the patella or if simple chondrectomy is deemed to be sufficient steps must be taken to prevent the recurrences of the deformities this is achieved best by transplantation of the tibial tubercle to the medial aspect of the tibia and transference of the tendon of the semitendinosus to the medial side of the patella as described on pages 193 to 195 A median parapatellar incision facilitates the execution of these precautions

Remodeling of Patella. This procedure is indicated when the surgeon is of the opinion that simple chondrectomy is not sufficient to achieve the desired results. The joint is exposed in a similar manner as when chondrectomy is performed using a median parapatellar incision The entire articular surface of the patella including a layer of subchondral bone is removed with a thin blade saw, now the patella is reduced to one half its original thickness Next the entire periphery of the patella is trimmed removing all excrescencies sufficient bone is cut away until the patella will move up and down the intercondylar surface without obstruction The raw patellar surface is covered with a layer of fat obtained from the infrapatellar region Frequently, this procedure is employed by the author in combination with synovectomy and débridement of the knee joint

Recently the author has been impressed by the results obtained following the replacement of the patella with a vitallium prosthesis designed by D C McKeever The prosthesis can be employed in all cases in which chondrectomy (partial or complete) patellectomy and remodeling of the patella are indicated The results are so striking that the author has decided to utilize this method The joint is exposed through a median parapatellar incision and the patella is displaced outward with its articular surface facing upward The margins of the patella its articular surface and a portion of the subchondral bone are removed so that the remodeled bone fits perfectly the mold depicted in Figure 194 Next the patellar prosthesis is placed over the reshaped patella and fixed firmly in place by a transfixion screw By turning the prosthesis 180° it can be used either to replace a right or a left patella The wound is closed in the usual manner and restoration of function is started immediately within the first 24 or 48 hours The method should be particularly useful in cases of patellofemoral arthritis

Arthrodesis. Obliteration of the joint space by a bony ankylosis is a useful proce

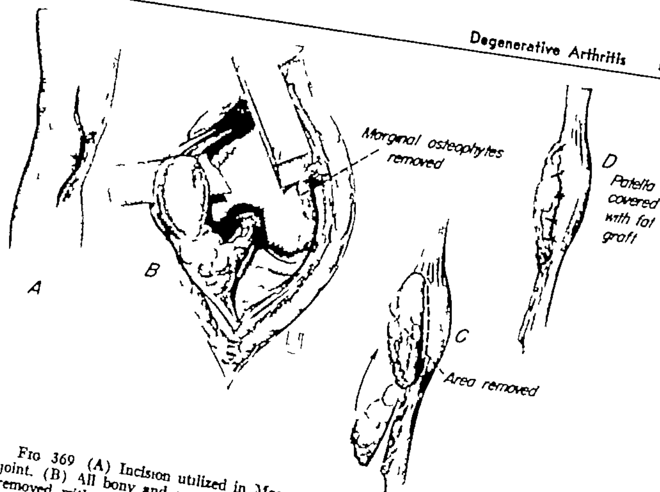


FIG 369 (A) Incision utilized in Magnuson's débridement operation of the knee joint. (B) All bony and cartilaginous excrescences on the femur and the tibia are removed with an osteotome All diseased cartilage is removed from the femoral condyles and the tibia with a sharp thin blade knife. (C D) The articular surface and part of the subchondral bone of the patella are removed and covered with a layer of fat. If necessary the author also performs a synovectomy and removes the menisci when they are diseased.

dure in cases with severe involvement of a single knee joint particularly when it is essential that the patient be ambulatory or his occupation demands long hours of standing and walking This method provides a painless useful limb and is recommended in selected cases with profound disintegration of the joint. The many methods of arthrodesis are described in Chapter 13 Surgical Approaches and Procedures the author prefers the compression method

Débridement of Knee Joint. The work of Magnuson and other investigators discloses that the end products of degenerative arthritis particularly peripheral exostosis and ecchondroses change the mechanics of the affected joint to such a degree that the articulation is constantly subjected to microtraumas and abnormal stresses These factors are prone to enhance the pathologic processes already present. In the light of this observation one can conclude reasonably that deletion of the mechanical irritants should result in amelioration of symptoms and improved function The results obtained by many workers justify this premise Magnuson in his original article did not recommend removal of the synovialis except in cases of rheumatoid arthritis However in cases showing advanced proliferation of the synovial lining the author combines Magnuson's procedure with synovectomy These results have been encouraging the procedure relieves pain and restores useful motion even in knee joints exhibiting profound destruction of the articular surfaces

of the femur the tibia and the patella. The denuded articular areas eventually are covered completely with fibrocartilage which forms a smooth gliding surface and permits free unobstructed motion In addition, deletion of the mechanical irritants deters the progression of the pathologic processes and in some instances stops the progression of the disease

The author employs this procedure also in cases often designated as "mixed arthritis These articulations exhibit all the cartilaginous and osseous features of degenerative arthritis and the thickened, hyperplastic synovial membrane encountered in rheumatoid arthritis These joints may represent the end products of a simple chronic villous synovitis which eventually induced secondary joint changes consistent with degenerative arthritis The true pathogenesis and the etiologic factors responsible for this lesion are not clear occasionally the disorder involves both knee joints (Fig 368)

The operation is performed under a tourniquet the joint is exposed through a long medial parapatellar incision (Fig 369) The medial attachment of the quadriceps is detached from the patellar attachment and the patella is displaced laterally By flexing the knee joint the anterior and inferior aspects of the femoral condyles and the superior surface of the tibia are brought into view With a thin bladed osteotome all osseous and osseocartilaginous growths are removed from the periphery of the articular surfaces of the femoral condyles Next with a long thin blade knife all defective cartilage is shaved from the articular surfaces taking care not to make transverse ridges or furrows in the cartilage which may act as obstructions to free motion It may be necessary to remove degenerated cartilage as far as the subchondral bone The articular surface of the patella is removed by a thin blade osteotome or a saw and its length and width are reduced so that it moves freely on the articular surfaces of the femur The raw surface of the patella is covered with a layer of fat obtained from the infrapatellar fat pad (It appears to the author that the use of a patellar prosthesis may be a useful addition to this procedure)

All degenerated cartilage on the upper surface of the tibia is excised and the remaining surfaces are made smooth the menisci are removed only if they show degeneration Likewise exostoses at the articular margin of the tibia are removed and all rough spicules and projections are leveled off If the synovial lining is thickened and edematous synovectomy is performed As much of the synovial lining as is accessible is removed Generally, it is not necessary to remove the membrane in the posterior recesses of the joint Débridement is now complete the wound is closed in layers in the usual manner A snug compression bandage is applied holding the knee in extension The limb is elevated for several days on a balanced suspension frame Traction to the lower leg may be applied but the author has not found this precaution to be necessary

Postoperative Management. This is an essential part of the treatment Quadriceps drill is started on the second or the third day This is followed by straight leg raising exercises against elastic resistance and later against increasing loads On the tenth to the fourteenth day weight-bearing is started with crutches Unprotected weight bearing is not allowed until the quadriceps has attained good power and tone Physical measures in the form of heat massage whirlpool and underwater exercises enhance restoration of function and decrease the period of convalescence If the patient achieves 90 flexion and complete extension the result from a clinical and functional viewpoint must be considered good

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Roentgen Therapy in Degenerative Arthritis

The literature contains reports of cases of degenerative arthritis benefited by irra diation In advanced cases of degenerative arthritis of the knee joints mechanical disalignment caused by marginal exostoses and ecchondroses loose bodies and incongruity of articular surfaces are the prime factors for propagation of the disease and accentu ation of the symptoms. Roentgen therapy offers little toward the correction of these conditions The author never has been im pressed by the results of this form of ther apy However some observers report a high incidence of good results in properly selected cases they claim that the treatment has an analgesic effect and is indicated in cases with persistent stiffness and pain

Ankylosis of Knee Joint Following Severe Trauma

In contrast with minor or microtraumas which initiate degenerative arthritis, occa



Fig 370 Severe comminuted fracture of the tibial plateaus. This patient had no free motion. An arthrodesis was per formed, at operation a fibrous anky losis was encountered

sionally severe violence may produce so much joint damage that the stage is set for the development of fibrous or bony anky losis Such injuries occur more frequently than is generally realized Essentially, the trauma produces comminution of the artic ular surfaces of one or both bones compris ing the joint the articular surfaces are often compressed and telescoped into the cancellous bone, such injuries implicate the tibial plateaus more frequently than the femoral condyles Ankylosis may follow dislocations in which there is severe disruption of the ligamentous apparatus and severe

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Fig 370 Severe comminuted fracture of the tibial plateaus This patient had no free motion An arthrodesis was performed at operation a fibrous ankylosis was encountered.

compound fractures with or without secondary infection

Essentially, ankylosis is the product of an active reparative process which follows *severe joint fractures Invariably the joint* is distended with blood some of which is not absorbed and is the basis for the formation of adhesions. Granulation tissue grows from the subchondral marrow spaces beneath the fractured surfaces and projects into the joint cavity to meet similar tissue formed on the opposing articular surface Reparative tissue also arises in great abundance from damaged ligaments, capsule and synovialis This tissue forms a panus over the articular surfaces absorbing hyaline cartilage and uniting the two bone ends by young connective tissue. With maturation of the granulation tissue stout fibrous adhesions are formed producing a true fibrous ankylosis Concurrently similar changes occur at the periphery of the joint where the synovial membrane is active in the formation of numerous binding fibrous adhesions In addition the suprapatellar pouch the posterior and the lateral synovial recesses are obliterated and coalesce into a single mass of fibrous tissue (Fig 370) Occasionally the process goes one step further—the fibrous tissue undergoes ossification and a bony ankylosis is established

Comprehension of the aforementioned process makes it apparent that long periods of immobilization enhance ankylosis of the knee joint when traumatized severely On the other hand early motion tends to prevent the formation of intra articular adhesions Fibrous ankylosis may permit a small range of motion which usually is painful bony ankylosis is not painful but the joint may not be in the most useful position of function It becomes obvious that when a knee joint has sustained severe intra articular fractures every effort should be made to institute early motion if no contraindications exist Traction methods which allow motion are far superior to complete immobilization of the limb in a plaster cast When ankylosis of the knee appears to be inevitable the limb should be immobilized in the position of function usually 10 to 12 of flexion Once ankylosis is established *joint motion can be restored only by performing an arthroplasty* The results of arthroplasties performed for cases with post traumatic bony ankylosis are better than arthroplasties performed on knees with chronic arthritis

Fibrous ankylosis complete or partial, is often observed in the knee joint following injuries at a distance from the joint when protracted immobilization of the limb is necessary to achieve healing of the injured part. The problems of the stiff knee are discussed in Chapter 10

MENOPAUSAL ARTHRITIS

That degenerative arthritis often makes its appearance or if present is accentuated during the menopause cannot be denied The symptoms observed at the climacteric period have been responsible for incrimination of the ovaries the anterior pituitary and even the thyroid glands as the causative agents. However no convincing evidence has been produced to justify any true relationship between dysfunction of the endocrine system and rheumatic manifestations observed in or about the menopause On the continent many observers are of the opinion that menopausal arthritis is a distinct form of arthritis apart from degenerative arthritis. In America most workers are of the opinion that the disorder is degenerative arthritis developing during the menopausal years. It may well be that obesity so frequently observed in the climacteric years may play a role in development of the disease the knees and the spine are affected most commonly

Menopausal arthralgia must not be confused with arthritis The symptoms are recognized as menopausal manifestations they are not confined to the joint per se but implicate connective and muscle tissue in

general particularly in the region of the neck, the shoulders and the lower back This form of arthralgia responds quickly to the administration of estrogens

HEMOPHILIC ARTHRITIS

Hemophilia is a hemorrhagic diatheses which is transmitted to the males by the females. The hereditary and familial characteristics of this disease have been recognized for many centuries, however, inheritance in many cases cannot be ascertained because the trait has been transmitted through several generations of women The pertinent features of the malady are failure of the blood to clot and prolonged bleeding time Quick proposes that lack of thromboplastenogen is the etiologic factor responsible for the disease and believes that the most accurate test of hemophilia is the determination of thromboplastenogen by estimating the prothrombin consumption time

Bleeding into the joints is a common concomitant manifestation of the disease hemarthrosis may be spontaneous or may follow varying degrees of trauma Frequently, minor traumas may initiate massive bleeding into a joint cavity The tendency to bleeding is usually recognized after the period of infancy During this time the child is carefully protected from any form of injury hence the purpuric tendency may not be recognized Hemarthroses usually have their onset between the ages of 4 and 10 years As noted previously, the bleeding may be spontaneous or may be precipitated by trauma Trauma in this period of life plays an important role The parents must restrain constantly the child's activities in order to keep the incidence of trauma at a minimum Generally the weight bearing joints are involved most frequently, the knee is implicated most often, but all joints of the body may be affected As the child approaches adulthood there is a tendency for hemophilia to improve Unfortunately joints, particularly the knee, that have been frequent sites of hemorrhages develop irreversible articular changes which produce severe and permanent dysfunction Occasionally, hemarthrosis is the first clinical manifestation of the disorder

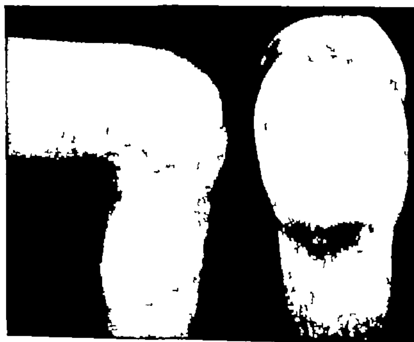


FIG 371 Massive intra articular hemorrhage of the knee joint of a boy 9 years old. Note the marked distention of the capsule and the pericapsular tissues.



FIG 372 Recent hemorrhage in the knee joint of a boy 8 years old Observe that (1) The distended capsule is visualized distinctly (2) The blood casts a shadow denser than the surrounding tissues (3) The suprapatellar pouch and the posterior portion of the capsule are distended (4) The articular cartilaginous elements show no significant alterations

CLINICAL FEATURES

The manifestations are governed by the amount of bleeding into the joint In most instances traumas of varying degrees are followed by rapid swelling of the joint Invariably in large hemorrhages there is intense pain and muscle spasm fixing the knee in a flexed position Massive intra articular hemorrhages may cause marked distention of the capsule and the pericapsular tissues In such cases the knee is hot and the skin is stretched and sensitive (Fig 371) In rare instances the capsule may rupture and the blood infiltrates the soft tissues if bleeding continues, the constant pressure on the soft tissues may result in massive sloughs of all the layers covering the anterior surface of the knee joint This sequence of events occurred in Case J C. (Fig 199), necessitating block excision of the necrotic tissue the denuded area was covered with split thickness grafts (Fig 200) Fortunately such cases as the one cited are rare. In most instances mild extracapsular hemorrhages occur, producing purplish discoloration of the periarticular tissues Some systemic reaction is usually present and is manifest by slight elevation of the temperature and a high leukocyte count usually the coagulation time is elevated

Roentgenographic study in the early stages of the disease shows no significant finding in the bony and the cartilaginous elements of the joint In the presence of a hemarthrosis the capsule is visualized distinctly It is distended with blood which casts a denser shadow than the surrounding periarticular structures The outline of the joint recesses are discernible (Fig 372)

PATHOLOGIC ALTERATIONS IN JOINT CONSTITUENTS

All the intra-articular structures the synovialis and the capsule exhibit deleterious effects produced by repeated hemorrhages and increased intracapsular tension associated with massive hemarthroses The products of disintegrated blood cells are irritants to the delicate synovial membrane During an episode of bleeding the synovialis becomes impregnated with blood pigment first, it is yellowish in color later it becomes reddish brown The response of the synovialis to repeated hemarthroses is evident in the formation of numerous villi and hyperplasia of all its layers Following the first few hemorrhages into the joint the synovial tissue returns to normalcy however after numerous episodes it becomes hyperplastic and thickened by fibrous tissue likewise the subsynovial stratum



FIG 373 (*Left*) Roentgenogram of the knee joint of a hemophiliac, aged 22 (postmortem specimen) Observe the areas of thinned cartilage the punched-out areas in the subchondral bone and the subchondral sclerosis of the lateral femoral and the lateral tibial condyles Some marginal proliferation in the form of bony spurs is also discernible (*Right*) The left (*top*) unaffected and the right (*bottom*) affected shoulder of the same individual. The right shoulder reveals advanced destructive changes the subchondral cysts are visualized clearly

shows an active reparative process. It too becomes thickened by fibrous tissue and is impregnated with blood pigments and iron Macrophages containing iron and other elements of red blood cells are demonstrable in the subsynovial tissue

Although little change is evident in the articular cartilage in the early stages of the disease repeated hemarthroses are associated with degenerative alterations in the cartilage It is believed that the blood displaces the synovial fluid which is the source of nutrient materials for the articular cartilage Increased intra-articular pressure also plays a role in initiating these changes In addition the author is of the opinion that hemophilic blood may contain some toxic element which has an affinity for hyaline cartilage and in a measure enhances destruction of this tissue this concept is now under investigation the results of which will be reported later Areas of cartilage are thinned later erosion of the articular structure is discernible these areas appear to be punched out and frequently extend deeply into the subchondral bone (Fig 373) They are observed both in nonweight bearing as well as weight bearing areas

In cases of long standing in which repeated episodes have occurred, the cancellous bone becomes porotic. However areas of subchondral sclerosis are noted at points of maximum weight bearing Formation of subchondral cysts is characteristic of hemophilic arthritis Key proposed that these cysts represent localized hemorrhages in the subchondral bone the bony trabeculae within the hematoma first undergo aseptic necrosis later, resorption takes place. This process results in the formation of bone cysts varying in size but rarely exceeding 1 cm. in diameter which are readily discernible on roentgenograms Marginal proliferation in the form of bony spurs is encountered in old cases essentially, they are similar to peripheral osteophytes observed in degenerative arthritis which develop after repeated trauma to the cartilaginous surface (Fig 374) Roentgenographic study reveals the spotty irregular destruction of the artic

ular surfaces especially of the tibial plateau a feature highly typical of hemophilic arthritis Marginal erosions in the bone at the line of attachment of the capsule are observed frequently

Although osseous ankylosis is rare in hemophilia fibrous ankylosis is encountered frequently Careful study of four knee joints obtained postmortem from four different individuals in which the process in the affected knees had progressed to fibrous ankylosis revealed some significant information The entire joint cavity is obliterated by firm tenacious fibrous adhesions stretching from the articular surfaces of the tibia to the opposing surfaces of the femoral condyles All the joint recesses are obliterated by a dense mass of fibrous tissue After the bone ends were forced apart the articular surfaces were found to be covered by a thick panus which grew from the subchondral bone through crevices between areas of deteriorated hyaline cartilage The fibrous tissue within the joint was reddish brown in color as were the remaining isles of hyaline cartilage So firm were the adhesions binding the femur the tibia and the patella together that considerable force was expended to flex the knee joint in fact it was necessary to cut some of the adhesions with a scalpel (Fig 375)

Flexion Deformities

Following repeated episodes of hemarthrosis frequently varying degrees of flexion deformities are encountered In the beginning during an acute bout of bleeding the knee assumes the position of flexion because this is the position of comfort and also because when the capsule is distended completely normally the joint is forced into flexion In addition spasm of the hamstrings tends to maintain the deformity If recovery after each attack is delayed or if management during the episode is inadequate fibrosis in the posterior portion of the capsule and contracture of hamstrings ensue The author has had under treatment



Fig 374 Right knee joint of a hemophiliac 36 years old Note the decreased medial joint space and the irregularity of the opposing articular surfaces of the medial joint space also note the marginal proliferation These features are not unlike those noted in degenerative arthritis

numerous cases ranging in age from 5 to 15 years with resistent flexion contractures of one knee joint Inasmuch as these patients walked with the knee flexed the knee, as well as the hip and the ankle on the same side were subjected constantly to abnormal stresses which made the joints vulnerable to repeated hemorrhages It becomes apparent that every effort should be made to prevent flexion contractures of the knee joint these are the most difficult forms of deformities to correct since open operation is prohibited except under unusual circumstances and because even minor forces may precipitate a new hemarthrosis

MANAGEMENT

Recent Hemarthrosis. One must bear in mind that most hemarthroses occur spontaneously, and occasionally the knee or some other joint may be one of several sites of bleeding concurrently In one case, hemarthrosis of the elbow was the reason for bringing the child to the hospital, on admission a massive hemothorax was found which could not be controlled for several days during this interval the child was almost exsanguinated It becomes obvious that a search for other bleeding sites is essential before local treatment to the affected knee is started

Up to very recently the author employed the orthodox methods of treatment in these cases which comprise enforced rest compression bandages and application of cold compresses Small transfusions of 200 cc. of whole blood given daily or every second day until bleeding is controlled is a valuable therapeutic measure The value of endocrine preparations to control hemorrhage is questionable

Within the past year the author has been impressed by the use of hyaluronidase in promoting rapid absorption of the hemarthrosis relieving pain and muscle spasm and permitting free painless motion in the affected joint within a period of 24 to 48 hours after injection Rapid dispersal of



FIG 375 Knee joint of a hemophiliac, aged 27 (postmortem specimen) The inner joint cavity is obliterated by tough fibrous adhesions stretching between the all-opposing articular surfaces. Likewise, the joint recesses are obliterated by dense fibrous tissue The bone ends are covered by a thick panus growing through crevices between areas of degenerative hyaline cartilage. The process is comparable with fibrous ankylosis of the knee joint In addition the pericapsular tissues were markedly thickened and showed advanced fibrosis.

blood in a joint not only prevents prolifera tive changes in the synovialis and degen erative changes in the articular cartilage but it also prevents flexion contractures of the *knee joint subsequent to fibrosis induced by* long periods of immobilization.

The efficacy of this method is based on the physiologic action of hyaluronidase This enzyme acts on the ground substance in the intercellular substrate it induces depolymerization of the principal element of the ground substance which is the muco-*polysaccharide hyaluronic acid With de* polymerization of this substance inter change and dispersion of tissue fluids are enhanced this process is aided further by the application of external pressure Hyal uronidase acts in other ways (1) it de creases the viscosity of the synovial fluid by acting on the hyaluronic acid and (2) it increases the permeability of the synovial membrane From the aforementioned ob-servations it becomes obvious that the enzyme will accelerate absorption of blood from a joint this observation was recorded by Britton and Habif The results reported by MacAusland and Gartland and those ob-served on the Jefferson Orthopedic and Medical Wards following the injection of hyaluronidase in acute hemarthrosis justify the author in recommending its use par ticularly in hemarthrosis in the hemophilic patient

The following technic is employed After the diagnosis of an acute hemarthrosis is established and the usual routine blood studies are completed steps are taken to reduce the clotting time and stop bleeding by the administration of plasma or fresh whole blood Under aseptic technic 4 or 5 cc. of blood is aspirated with the same needle in situ 1 000 units of hyaluronidase mixed with 1 per cent procaine is injected into the joint cavity The amount of fluid instilled into the joint is equal to the amount of blood withdrawn usually 4 or 5 cc The joint is not evacuated at the time of aspiration At the termination of the instillation a sterile pad of gauze is pressed firmly against the puncture site then a snug fitting elastic bandage is ap-plied to make uniform pressure The joint *is placed at complete rest for 24 hours* at the end of this period the limb is re-evalu ated If swelling pain and spasm are still predominant features the injection is re peated.

Generally at the end of the first 24-hour period distention is reduced markedly muscle spasm is minimal and pain is re *lieved to a great extent or even absent* at the end of the second 24 hour period pain is relieved completely and a free range of active and passive motion is present which generally is equal to the range prior to the onset of the hemarthrosis. Unrestricted motion in the upper limb and weight bearing on the lower is permitted at the end of the 48-hour period It is obvious that such rapid absorption of blood precludes the formation of villous synovitis also, the del eterious effect of blood on the cartilage and the subchondral bone is minimized and the processes leading to arthritis and fibrosis of soft tissues with contractures are aborted or retarded

Fixed Contractures in Hemophilic Arthritis As noted previously every effort must be expended to prevent even minor flexion deformities of the knee joints When present they must be corrected in order to preclude abnormal stresses on an already damaged joint Minor deformities may be corrected by the turnbuckle method as de scribed on page 568 However great care must be utilized one must proceed cau tiously and slowly When correction has been achieved it can be maintained by the use of a celluloid cylinder until muscle power is adequate to stabilize the joint and protect it from trauma incident to normal function The same method is employed in more severe deformities. It has been the author s experience that in most cases in the latter group posterior subluxation of the tibia invariably occurs In many joints the

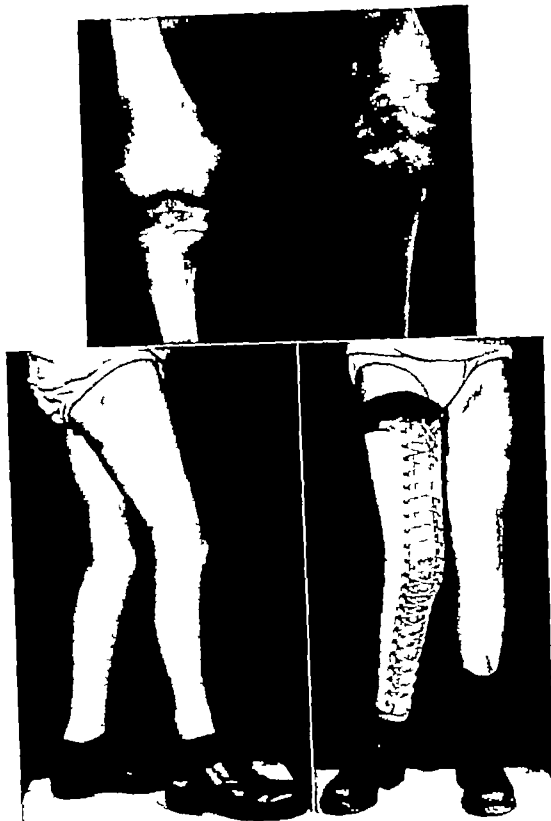


Fig 376 (*Top*) Hemophiliac with severe cartilaginous alterations of the right knee joint observe the thin joint spaces, the irregularity of the articular surfaces and the marked osteoporosis of the femur and the tibia. (*Bottom left*) This patient has a fixed flexion contracture of the joint with external rotation of the tibia no more than 10° to 12° of motion were demonstrable passively or actively (*Bottom right*) Same patient wearing a celluloid cylinder for protection Further correction of the joint is not possible surgical intervention is contraindicated



Fig 377 (A) Unusual case of severe gout in a Negro aged 37 Note the tophi in the ear

subluxation is present before correction is attempted and it is complicated further by external rotation of the tibia resulting from contractures of the tensor fascia lata and the biceps femoris muscle In these cases the tibial deformity must be accepted because the hemorrhagic diathesis of the patient precludes any more drastic methods such as compound traction posterior capsulotomy or capsuloplasty When the alterations of the joint components are severe and at best only a few degrees of motion in the knee joint can be anticipated the author is of the opinion that ankylosis of the knee in the position of function should be the aim of the treatment This can be achieved by immobilization of the limb in a celluloid cylinder until ankylosis is complete Surgical arthrodesis is contraindicated (Fig 376)

GOUT

Gout has been recorded in the earliest medical literature The significance of uric acid in the disease was first recognized in 1776 by Scheele and Bergman Although Sydenham was aware that gout and rheumatoid arthritis were two different entities it was Heberden who recorded the cardinal features separating the two diseases. In 1847 Garrod demonstrated increased uric acid in the blood of patients affected with gout It is difficult to determine the true incidence of gout in patients with arthritic complaints the figures vary for 2 to 5 per cent It is generally accepted that gout is a disease of people living in abundance of food and drink and engaged in sedentary occupations Gout is predominately encountered in males the incidence in males in the numerous series reported ranges from 93 to 98 per cent

That gout is a hereditary disease is established the tendency is most likely transmitted by the females in spite of the fact that they themselves rarely show clinical manifestations It has been recorded that approximately 25 per cent of relatives of a gouty patient showing no clinical symptoms of the disease have hyperuricemia Essentially gout is a disease of adult males although it is observed occasionally in elderly women in men it is usually noted between the ages of 30 and 50 years however cases have been recorded in children under 10 years Negroes are rarely affected yet the most severe case of gout that the author has encountered was in a Negro 37 years of age (Fig 377) the process had been active for 10 years and resisted all forms of therapy

Etiology

The etiology of gout is not known however some evidence points to the possibility that androgenic activity may be closely related to gout In support of this premise Traut points to the predilection of men to develop gout the disease is rarely observed before puberty when found in women it tends to be manifest at the climacteric and it is rarely encountered in eunuchs Also in both males and females the hyperuricemia

usually develops during the period of life characterized by a relative increase in an*drogen unantagonized by estrogen*" This observer further noted that "gouty androgen" is presumed to originate in the adrenal cortex. The cholesterol falls in prodromal periods of gouty arthritis corresponding to increased activity of the adrenal cortex. All concede that gout is a manifestation of disturbed metabolism of uric acid however, the mechanism responsible for this metabolic abnormality is highly speculative. One would expect that elevations in the uric acid *content in the blood invariably would in*itiate an acute episode this, however, is not the case hyperuricemia may be present for many months and even years without clinical manifestations Uric acid in man represents the end product of purin metabolism, unfortunately, man and the anthropoid apes lack the mechanism to synthesize this substance as is done in lower animals through



Fig 377 (B and C) Same case exhibiting severe deformities of the lower and the upper extremities

the medium of the enzyme uricase Normally, uric acid which is a threshold substance is eliminated by the glomeruli and reabsorbed in part by the tubules of the kidneys It appears that in gout the hyperuricemia may be in a measure the result of excessive reabsorption by the kidney tubules this tendency discloses the affinity that renal tissue has for urates Evidence at hand indicates that in the gouty, an abnormal tendency exists to deposit urates in *the mesenchymal tissues In uncomplicated* gout retention of uric acid occurs prior to an acute episode this is followed by increased excretion during and retention following the attack other nitrogenous products are not increased in the blood This is in contrast with old cases of gout with varying degrees of renal damage in which all the nitrogenous blood constituents especially urea and creatine are increased Increase in the amount of uric acid in the blood does *not govern the deposition of urates in tis*sues hyperuricemia may be present for years without clinical manifestation in the mesenchymal tissues Accumulating evidence suggests that some hormonal influence is responsible for the behavior of uric acid in the blood The increase in uric acid excretion following administration of ACTH indicates that in some way the adrenal cortex may be the governing agent

It is believed that change of the colloidal state of uric acid in the blood is responsible for its crystallization and deposition in fixed tissues There is a close relation between the concentration of the purin in colloidal state and the content of sodium chloride present the higher the concentration of the sodium salt the less the ability to maintain the urate in suspension Disturbances in electro*lytes and water balance invariably exist in* the prodromal period of an acute episode this usually comprises diuresis and a negative sodium chloride balance In addition calcium potassium phosphate and ammonia are lost Mesenchymal tissues such as tendons and cartilage contain higher levels of sodium salts than blood this affords an explanation for the great tendency of these tissues to fix uric acid

Pathology

In gout urates in the form of sodium biurate show predilection for such mesenchymal tissues as cartilage tendons capsules and bone They have been observed also in the meninges the pleura the pericardium the brain and the spinal cord It is generally accepted that the urate deposit

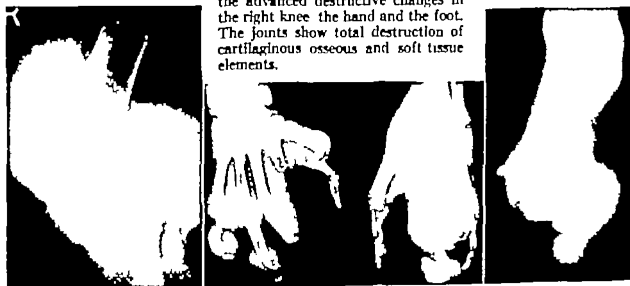


Fig 377 (D E and F) *Exhibiting* the advanced destructive changes in the right knee the hand and the foot. The joints show total destruction of cartilaginous osseous and soft tissue elements.

(chalky mass) in symptomatic gout is associated with a local inflammatory reaction which produces focal necrosis of the mesenchymal tissue. In cartilage the urate crystals are deposited in the superficial layers causing fibrillation of the cartilage between the deposits Eventually, the cartilage overlying the deposits (tophi) is destroyed completely, now the mass of crystals is in direct contact with the joint cavity and the synovial fluid It is believed that intra-articular tophi are derived from urates in the synovial fluid The inflammatory reaction surrounding the tophi is characterized by the formation of granulation tissue, exhibiting numerous leukocytes round cells and giant cells the last are macrophages commonly observed in foreign body reactions in addition the surrounded tissue is edematous and hyperemic The inflammatory response causes softening and partial resorption of the tophi Concomitant with an acute attack, a fine panus of granulation tissue may project from the synovial membrane, forming an irregular panus over portions of the articular cartilage both intra articular and periarticular fluid are increased so that the joint may become markedly distended Usually in early cases after the acute attack subsides the joint tissues and joint function return to normalcy After repeated attacks over the course of many years permanent alterations ensue which are similar to those of degenerative arthritis, usually the disease at this time is polyarticular

An acute exacerbation is accompanied generally by an inflammatory response in the periarticular tissues and skin The joint tissues become swollen reddened and tense the skin is shiny and the superficial views are engorged and tortuous. The process together with the systemic reaction which often is present has all the features of cellulitis Occasionally implication of superficial tophi leads to the formation of a phlegmon which ruptures through the skin and produces an ulcer or fistulae which discharge urates

As recorded previously, tophi comprises masses of urate crystals According to Hench, less than 50 per cent of all cases of gout, regardless of the stage of the disease exhibit tophi Frequently, they are observed in the helix of the ear and in or near joints, also, they are commonly noted in bursae and tendons, particularly the Achilles tendon and the olecranon bursa They vary in size from minute deposits measuring a few millimeters to large nodular masses measuring several centimeters It is interesting to note that in joints of the extremities tophi most frequently are first observed in extensor surfaces of the joint however involvement of the great toe is usually on the medial aspect of the joint In the early stages of development, the tophi are soft and even fluctuant later they become firm and discrete and the overlying skin may be tense Acute exacerbations of the disease are not related to the formation of tophi which cause no symptoms until necrosis and ulceration of the surrounding tissue occur

Clinical Manifestations

Not all cases of gout produce tophi or joint symptoms, the defective metabolism of purine may not be recognized for many years some cases never are associated with joint manifestations It is recorded that approximately 50 per cent of acute gouty episodes are ushered in with prodromal symptoms such as vague pain in the affected joint or gastric disturbances Characteristic of the disease is the sudden onset of the symptoms, comprising severe pain swelling discoloration and tenderness When discoloration is present, the affected part acquires a reddish blue color due to engorgement of the superficial views This is the classic clinical picture observed when the great toe is affected The pain may be so intense that pressure made by bedclothes is not bearable The symptoms gradually increase in gradient then after 2 to 6 days they recede until all symptoms disappear and function is restored

completely Usually acute episodes involve one joint In more severe and chronic cases polyarticular involvement may occur Usually this is associated with constitutional reactions of varying intensities After repeated attacks permanent articular changes ensue causing impaired function In chronic forms the joint may remain swollen tender and painful during the interval between acute exacerbations Severe deformities associated with advanced degenerative arthritis may occur although rare total invalidism has been observed by the author in one case (Fig 377) Increase in the serum



Fig 378 Roentgenograms of the knee exhibiting moderately advanced articular alterations associated with gout Note the atrophic loss of substance near the articular margins more pronounced in the medial condyle of the tibia and in the articular surface of the patella

uric acid content is now present at all times during acute attacks as well as during remissions

From 60 to 80 per cent of the patients have involvement of the great toe (podagara), the disease implicates the distal joints more frequently than the proximal The knee joints are not infrequent sites of involvement, whereas the spine and the shoulders are rarely involved The author has observed one acute episode resulting from involvement of the anterior surface of the patella, this was the patient's first attack, gout had not been suspected prior to this attack Clinical experience reveals that certain factors may initiate an acute episode of gout Chief among these are (1) trauma in various forms (2) overexertion, (3) excesses in eating and drinking, (4) surgical procedures and (5) injections of drugs such as mercurial salts, causing diuresis

Roentgenographic Features

Roentgenographic study may fail to disclose any demonstrable bony alterations in the affected joints, this is particularly true in early attacks However in acute gout there is diffuse soft tissue swelling of the joint roentgenograms of the great toe show this feature clearly Later, changes occur in the cartilage and the articular margins which are suggestive of gouty arthritis however these changes are not pathognomonic of the disease and may be observed in rheumatic and degenerative arthritis There is atrophic loss of substance at or near the articular margins the areas have an irregular punched-out appearance resembling cysts they comprise conglomerations of urate crystals which are radiolucent (Fig 378) In more severe cases advanced degenerative changes with joint destruction may be demonstrable Occasionally total destruction of the joint elements is discernible This results from deposition of large deposits of urates in the articular cartilage epiphysis and capsular tissues which eventually are totally destroyed (Fig 377) As noted previously, the aforementioned deposits are radiolucent however, in cases of long standing, some calcium finds its way into the topi these now become demonstrable roentgenographically

Diagnosis

Many cases of gout are not recognized because the attending physician fails to think of the disease as a possible etiologic factor responsible for the clinical manifestations exhibited by the patient Physicians practicing in England are more gout-conscious than any other group in the world this may explain why such a high incidence of gout is recorded in the English population An acute episode of gout associated with systemic reactions such as fever, leukocytosis and a hot, tender, swollen joint may simulate an acute infectious process, frequently, it is diagnosed erroneously as cellulitis Monoarticular involvement favors gout, simultaneous polyarticular involvement is exceedingly rare in gout. Failure to obtain pus on aspiration of the affected joint and negative cultures of the joint fluid tend to eliminate an infectious process A history of similar attacks in the same or other joints, followed by return to normalcy, is indicative of gout. The diagnosis is established if the urate crystals can be aspirated from the joint and demonstrated and if an increase in the uric acid content in the blood is present Also, gout must be distinguished from swelling or hemorrhage in joints following trauma As noted previously trauma, regardless of its nature, may precipitate an exacerbation of the disorder Rheumatoid arthritis and rheumatic fever may be confused with gout. The following features are characteristic of rheumatoid arthritis (1) it is common in women (2) symmetrical polyarticular involvement is the rule (3) affected joints tend to progress to a chronic state and never return to normalcy, (4) deformities occur early in the disease (5) the disease affects young individuals most frequently (6) there is no evidence of disturb-

ance in purine metabolism as determined by *study of the blood chemistry* and (7) renal complications so common in gout are rarely observed in rheumatoid arthritis

Rheumatic fever has the following features which differentiate it from gout (1) the disease usually affects children and young individuals, (2) it is polyarticular and exhibits migratory features (3) the general physical health of the patient is usually poor and is associated with anemia a feature rarely observed in gout and (4) cardiac involvement is common

Chronic gouty arthritis may be difficult to distinguish from joint changes resulting from rheumatoid or degenerative arthritis in cases of long standing The pertinent features suggesting gout in these instances are (1) a careful history of attacks followed by complete restoration of function and relief of pain (2) elevated uric acid levels in the plasma this is a constant finding in old established cases of gout (3) the presence of tophi from which sodium biurate crystals may be obtained and (4) roentgenograms exhibiting punched-out areas at the articular margins these findings are not pathognomonic of gout but they should be highly *suggestive of the disease*

Management

One must bear in mind that gout is a *hereditary defect that cannot be eradicated* by any form of therapy known to man The course of the disease is unpredictable some individuals never have clinical manifestations *in the joints* and existing cardiorenal complications may never be linked with the defect in purine metabolism Likewise the clinical pattern in cases of gout with joint involvement is variable. In general however in individuals developing joint deformities early in life the prognosis is more grave than in those exhibiting a tendency toward deformities late in life In spite of the hopelessness of effecting a cure much can be done to ameliorate the symptoms and reduce the joint and cardiorenal complications to a minimum This can be achieved only by full co-operation on the part of the patient It may mean divorcing the patient from harmful habits particularly abuses in eating and drinking

Patients known to have gout should be instructed in prophylactic measures which in many instances tend to lengthen the periods of remissions and decrease the intensity of an attack. The diet should be low in purine rich foods and fats fats are not only highly calorigenic foods but they also enhance urate retention On the other hand carbohydrates favor increased excretion of urates Obesity must be avoided and adequate intakes of fluids minerals and vitamins are essential all alcoholic beverages must be eliminated Gouty patients must be denied certain medications which may precipitate an acute episode notably among these are liver extracts mercurial diuretics and lead in any form Some authorities advocate the administration of colchicine (1/100 gr) 1 to 3 times daily for 4 or 5 days *of each week* The dose must be kept within the patient s tolerance which is below the diarrheal level Fortunately patients do not develop tolerance of the drug hence small *prophylactic doses do not affect the efficacy* of the drug when given in larger doses to terminate an acute gouty attack

The aforementioned precautions should *be employed in the preoperative and the* postoperative management of a patient subjected to a surgical procedure Prophylactic doses of colchicine (1/100 gr given 3 times *daily for 3 or 4 days prior to the operation* and for the same period postoperatively) may abort an acute episode In addition the patient should be protected from harmful environmental *factors which may initiate an* attack he should obtain adequate rest and mental relaxation he should avoid situations that irritate and disturb his mental peace *Finally he should understand his* limitations and make the necessary psychic adjustment

Acute exacerbations in gout are self

limited, however, much can be done to terminate the episode and relieve the patient of the intense pain. When the knee is implicated, it frequently becomes distended by massive synovial effusion, all motion is painful, and the joint is held in slight flexion Protection to such a joint is provided best by a posterior molded splint, cold dressings add to the patient's comfort. Large effusions should be aspirated, usually, compression dressings are not tolerated Most acute attacks respond to colchicine (1/100 gr) administered 2 to 4 times daily until the acute manifestations subside Other drugs that may be employed for their analgesic action are sodium salicylate acetyl salicylic acid and, for severe pain, codeine and morphine

The use of ACTH in acute attacks of gout is gaining favor It controls acute gouty arthritis rapidly within a period of several hours It is believed that the hormone stimulates the adrenal cortex to produce corticosteroids which terminate the attack it is reported that most cases are controlled within the first 24-hour period Unfortunately, following the administration of ACTH a deficiency in corticosteroids ensues invariably this induces a second attack unless measures are taken to prevent this undesirable sequel Colchicine administered in combination with ACTH is an effective method of preventing a second attack the dose of colchicine is maintained within the limits of the patient's tolerance for 10 to 14 days after all symptoms have subsided

When degenerative changes in the knee joint are established the treatment of the local condition in the intervals between acute attacks does not differ from that described for degenerative arthritis resulting from other causes. Besides maintaining constant vigilance over the daily habits of living these patients must avoid fatigue and pursue a plan of activity always within the functional capacity of the joint. Occasionally large tophi may cause pain such lesions are frequently not acceptable to the patient because of the undesirable cosmetic features The skin over large tophi may ulcerate, producing draining sinuses. The aforementioned objections justify surgical evacuation of the urate deposits Many times, the author has found that such procedures are indicated, particularly when the lesions involve the fingers and the toes, on two occasions tophi over the patella were excised

NEUROPATHIC ARTHROPATHIES

The grotesque deformities observed in neuropathic arthropathies have attracted the attention of workers for many decades Although the basic pathology does not differ from that noted in degenerative arthritis except in degree, neuropathic joints are invariably associated with lesions of the nervous system Charcot joint is synonymous with neuropathic arthropathy It has been recorded that 90 per cent of all Charcot joints are concomitant lesions of tabes dorsalis, the remaining are related to syringomyelia and infectious, neoplastic, congenital and traumatic lesions of the brain, the cord or the peripheral nerves. Of the last group neuro-arthropathies are most frequently associated with syringomyelia In 1831 Mitchel described neuropathic arthropathies encountered in cases with tuberculosis of the spine. The relation of tabes dorsalis to these lesions was noted and recorded by Charcot in 1868 The lesions have been described in association with diabetes (Foster and Bassett), arteriosclerosis paraplegia (De'ano) multiple sclerosis spina bifida poliomyelitis acute myelitis and toxic neuritis

Etiology

The early investigators proposed that neuropathic arthropathies were the result of impairment of the trophic centers' in the spinal cord This concept has been debated for many years finally the work of

Floesser in 1917 revealed some significant observations which shed some light on the pathogenesis of this disorder This observer noted that cutting of the posterior nerve roots of animals failed to produce Charcot joints however if in addition to cutting the posterior roots the joints of these animals were subjected to repeated trauma



FIG 379 (*Top*) Right knee joint of a female 51 years old When first examined on May 8 1952 the chief complaint was pain in the inner aspect of the knee joint following a twisting injury Physical and roentgenographic examination exhibited no evidence of a neuro-arthropathic joint (*Bottom*) The same knee 6 months after meniscectomy The joint is completely disrupted and reveals all the roentgenographic features of Charcot joint. The patient s serology both blood and spinal fluid was positive This is the atrophic variety of Charcot joint.

neuropathic arthropathies developed The significance of trauma in the development of Charcot joints became apparent There is evidence suggesting that the myelinated pain fibers responsible for rapid pain conduction are primarily involved, whereas the nonmyelinated fibers responsible for slow conduction of pain are unaffected (de Takats) In addition the nonmyelinated fibers function as vasodilator fibers the hyperemia observed in Charcot joints following repeated injuries is evidence that vasodilator fibers remain intact. That complete anesthesia is not present in all Charcot joints is supported by the clinical observation that in some painful stimuli may be noted but their interpretation is retarded again pointing to preservation of nonmyelinated fibers for slow conduction of pain Therefore complete anesthesia is not a prerequisite for the development of neuroarthropathic joint Repeated traumas incident to joint function inflicted on a joint with impaired sensation precipitate pathologic changes in the joint elements consistent with Charcot joints It is estimated that from 5 to 10 per cent of the cases of tabes dorsalis develop neuro-arthropathies The rapidity of development of a Charcot joint in most instances is governed by the multiplicity and the severity of the traumas Generally the more abnormal stresses are imposed on a joint, the more rapidly the joint alterations develop This affords an explanation for the high incidence of Charcot joints found in the weight bearing extremities as compared with that observed in the upper extremities On the other hand the author has observed rapid deterioration of what appeared to be a normal joint both clinically and roentgenographically following some surgical procedure on the knee joint The knee joints of 3 cases were subject to surgical procedures under the erroneous diagnosis of tear of one of the menisci Within 4 to 6 months after the operation a typical Charcot joint developed (Fig 379) Another case of interest in the author s files



Fig 380 Typical Charcot joint with posterior subluxation of the femur in a female, aged 41 The lesion developed 4 years after injury to the spinal cord sufficient to cause paraplegia lasting 4 years. Power returned to the left extremity but a neuro-arthropathic joint developed in the right knee joint.

is that of a woman 41 years old who developed thrombophlebitis of the right leg following an abdominal operation Someone attempted to perform a procaine block of the lumbar sympathetic ganglia but unfortunately traumatized the spinal cord This was followed by complete paraplegia approximately 4 years after the accident power returned gradually in the left extremity a typical Charcot joint developed in the right knee (Fig 380)



Fig 381 A case of multiple joint involvement Both the left knee and the ankle are implicated This patient is a tabetic 52 years old

PATHOLOGY

Essentially the alterations in the components of a Charcot joint do not differ from *those observed in degenerative arthritis* except that the destruction in the former is of greater severity Changes in the capsule and the synovial membrane occur early in the disease The analgesic joint is no longer protected by the highly specialized sensory innervation that has endowed the capsule the synovialis the ligaments and the muscles crossing the joint The synchondorous function between the ligaments and the *muscles which protect the knee joint is lost* The joint is now vulnerable to abnormal stress and to microtraumas incident to joint motion As noted previously such traumas produce synovial effusions and hemarthroses. Repeated episodes of this nature are responsible for marked thickening of the capsule and the synovial membrane The *synovialis may exhibit pronounced villous* formation The intra articular and the collateral ligaments together with the aforementioned structures become edematous thickened and stretched also there is progressive weakness of the muscular apparatus of the knee joint All the above factors in combination produce marked laxity of the supporting structures of the knee joint this together with the concomitant destruc*tion in the cartilaginous and the bony ele*ments of the joint produce varying degrees of subluxation or even dislocation Excessive abnormal mobility without evoking pain is the most pertinent clinical feature of a Charcot joint Formations of heterotopic bone and cartilage in the capsular tissues is characteristic of this disorder the formations vary in size and number and provide a source of loose bodies in the joint *cavity The periarticular bone may extend* considerable distances into the adjacent soft tissues

Unlike other types of chronic arthritides the articular cartilage in arthropathies undergoes destruction rapidly and early exposing the subchondral bone This alteration is more pronounced in the areas of greatest weight bearing Those areas not subjected constantly to friction are fre*quently covered with a panus comprising* granulation tissue arising from the edges of the synovial membrane and from the narrow spaces and fissures in the subchondral bone

The alterations in the bone ends comprise marginal fractures disintegration and atrophy without bone reaction marked proliferation of bone and eburnation If the process is long standing all these changes *may be seen in the same joint* Generally specific patterns in sequence are discernible In those instances where the process progresses rapidly atrophy and disorganization of the subchondral bone usually ensue whereas in slowly progressing lesions hyper

trophy and eburnation of the bone ends occur In contrast with the alterations observed in degenerative arthritis, hyper trophy of bone in arthropathies fails to provide stability or support to the joint because the defective bone usually is broken off and adds to the debris, consisting of pieces of bone cartilage and necrotic granulation tissue found in the joint Fissures, marginal fractures or fractures through the femoral or the tibial condyles are characteristic of the disease Often the tibial condyles are depressed, and their margins are worn away such lesions represent compression fractures resulting from extensive osteoporosis Although proliferation is active both in the capsular tissues and from the marrow spaces ankylosis of a Charcot joint never occurs This may result from the marked painless hypermobility that exists in these joints The activity of the proliferative process in some instances permits one to conclude that if rigid immobilization of the joint were possible, ankylosis should be achieved On the other hand, clinical experience reveals that many Charcot joints fail to attain ankylosis even after execution of carefully planned surgical procedures designed to produce an arthrodesis.

Clinical Features

Arthropathy usually implicates a single joint, most frequently the knee Involvement of the knee and the ankle of the same extremity is not uncommon (Figs. 381 and 382) As noted previously, neuropathic joints occur most frequently in the tabetics, the incidence in some series of cases being as high as 90 per cent, generally, the patients are over the age of 35 years

Symptoms referable to the joints may be the first clinical manifestations of tabes dorsalis the author has observed this many times The disease is noted more frequently in the weight bearing extremities than in the nonweight bearing Implication of both knees is a relatively frequent occurrence The earliest clinical feature is sudden swelling of the joint which represents the joint reaction to some form of abnormal stress or joint fracture In most instances, the neuropathy is observed first after advanced dis-



Fig 382 (*Left*) Neuro-arthropathic joint exhibiting hypertrophic features. The bone ends exhibit advanced condensation, observe the marked proliferation of new bone at the peripheries of the femur, the tibia and the patella (*Right*) In this patient the ankle joint of the same extremity is also involved

organization of the joint has occurred this is explained readily by the absence of severe pain which is characteristic of the disease In advanced cases the deformity resulting from the marked capsular thickening and subluxation or dislocation of the knee joint is readily apparent (Fig 380) The painless hypermobility is the result of several factors the most important being diminished sensitivity of the joint tissues stretching and rupture of the capsular and the ligamentous apparatuses and hypotonia, which is a sequel of degenerative changes in the spinal cord Passive manipulation of the limb invariably is accompanied by crepitus produced by one roughened bone grinding against another

One must bear in mind that in many instances the patients with arthropathies experience some discomfort and even pain in and about the affected joint occasionally the pain may be intense and in part may be the result of distention of the capsule by massive effusions or hemorrhage Although diminished sensitivity is the rule some tabetics exhibit rheumatic manifestations which are accentuated by changes in the weather

In addition to the local characteristic features tabetics exhibit other neurologic and systemic manifestations which aid in arriving at the correct diagnosis There is loss or diminution of position sense and in-co-ordination and failure of pupils to contract when exposed to light Small irregular pupils (Argyll Robertson pupils) are not always demonstrable in the tabetic. Tabetic crisis (lightning pains)
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of the extent of the destructive process in a Charcot joint The roentgenographic features vary greatly however, they fall into two main categories the atrophic and hypertrophic both may be discernible in the same joint

Atrophic Type. This variety is usually encountered in rapidly developing Charcot joints The process is entirely destructive new bone formation is minimal or absent The effusion tends to be massive bone destruction is at right angles to the thrust of weight bearing the bone ends are of normal density or exhibit rarefaction Although some irregular detritus is present at the periphery of the effusion cartilaginous and bony formations in the capsule or the adjacent tissues are lacking (Fig 379) It becomes apparent that the predominant processes are hyperemia and demineralization of the bone ends Under these conditions unprotected motion and repeated insults to the joint are followed by rapid disintegration of the joint with no attempt at new bone formation

Hypertrophic Type. Arthropathies in this group develop more slowly the destructive process is accompanied by an active proliferative process which is responsible for condensation of the bone ends and irregular defective bone formations simulating buttresses at the margins of the bones usually in the regions of maximum weight thrust In addition calcareous lippings or osteophytes at the joint margins are common concomitant findings these are irregular in configuration density and texture and differ from the sharply defined deposits observed in uncomplicated degenerative arthritis Loose bodies comprising
gular detritus varying in shape texture
density are observed within and at the
joint cavity (Fig 382)
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MANAGEMENT

Adequate treatment should be governed by the knowledge that a Charcot joint is the product of established degenerative alterations in the cord and that repeated insults to the joint incident to joint function are prime factors in the development of the arthropathy Also, certain clinical observations should be considered before a choice of therapy is made Successful arthrodeses are difficult to achieve, however the reports of some workers indicated that arthrodesis can be obtained by special surgical technic. The author has had satisfactory results by the use of the elastic compression methods as described in Chapter 13 "Surgical Approaches and Procedures" On the other hand Key brings to our attention that one third of the patients with a single neuropathic joint develop another sometime during the course of the disease This knowledge certainly influences the choice of such procedures as arthrodeses and amputations Tabetic patients may have difficulty in mastering a prosthesis or a limb with a stiff knee because of the defective sense of position

The most effective form of conservative treatment is the application of some form of external support which allows ambulation and protects the joint from further injuries This measure should be employed as early as possible in the development of the arthropathy and preferably before advanced joint destruction occurs A brace does not eliminate completely the traumatic factor but it does diminish its intensity For the knee the author utilizes a brace with an ischial weight bearing ring and a lock joint at the knee

If, after adequate evaluation of the patient one feels that arthrodesis of the knee joint is indicated a procedure should be chosen which minimizes the period of bed rest enhances rapid ankylosis and permits early ambulation The author prefers the elastic compression method noted above In involvement of multiple joints of the same limb, including the knee and in cases of failure to attain stabilization of the knee joint with arthrodesing operations amputation above the knee joint is indicated

It is understood that treatment of the arthropathy should be carried out, together with treatment of the systemic disease, in cases of tabes dorsalis Antisyphilitic therapy will not reverse the destructive changes in the joint, but the patient can be relieved of lightning pains Also, the active disease is controlled and the general health of the patient is improved

PYOGENIC ARTHRITIS

Involvement of a joint by pyogenic organisms is a tragedy Prior to the advent of chemotherapy and antibiotics both surgeon and patient were faced with a serious struggle not only to save the limb but also the patient's life. The aforementioned therapeutic agents have modified, in a measure, the seriousness of the condition Nevertheless, once a joint is implicated, complete return to normalcy is rarely achieved at best some residual dysfunction must be anticipated because of the damage sustained by the articular cartilage Even at the present time it is not uncommon to observe complete destruction of a joint by a pyogenic process. However, when such a disaster occurs, it must be admitted that adequate treatment was not instituted or was started too late Fortunately the popular free use of antibiotics has reduced considerably the incidence of suppurative arthritis The most common avenue of inoculating the joint with the organism is usually by way of the blood stream also penetrating wounds of the joint frequently are complicated by a suppurative arthritis This is a common occurrence on the battlefield occasionally direct inoculation occurs during a surgical procedure.

ETIOLOGY

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In addition to the local characteristic features tabetics exhibit other neurologic and systemic manifestations which aid in arriving at the correct diagnosis There is loss or diminution of position sense and in-co-ordination and failure of pupils to contract when exposed to light Small irregular pupils (Argyll Robertson pupils) are not always demonstrable in the tabetic Tabetic crisis (lightning pains) and incontinence may be present Serologic examination of the blood and the spinal fluid of cases of tabes dorsalis may fail to provide evidence supporting the diagnosis Both Wassermann and Kahn tests made on blood and spinal fluid are recorded to be negative in approximately 50 per cent of the cases

Roentgenographic Features

The clinical features give no indications of the extent of the destructive process in a Charcot joint The roentgenographic features vary greatly however they fall into two main categories, the atrophic and hypertrophic, both may be discernible in the ame joint.

Atrophic Type. This variety is usually encountered in rapidly developing Charcot joints The process is entirely destructive new bone formation is minimal or absent. The effusion tends to be massive bone destruction is at right angles to the thrust of weight bearing the bone ends are of normal density or exhibit rarefaction Although some irregular detritus is present at the periphery of the effusion cartilaginous and bony formations in the capsule or the adjacent tissues are lacking (Fig 379) It becomes apparent that the predominant processes are hyperemia and demineralization of the bone ends Under these conditions unprotected motion and repeated insults to the joint are followed by rapid disintegration of the joint with no attempt at new bone formation

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As mentioned previously ankylosis of neuropathic joints does not occur varying degrees of subluxation and even dislocation are noted roentgenographically This displacement may be in any plane (Fig 380)

Management

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Etiology

The organisms which are the most com

mon offenders are hemolytic streptococci staphylococci gonococci, meningococci and pneumococci however, practically all pyogenic organisms are known to be capable of entering a joint cavity and producing a suppurative process Pyogenic arthritis is a relatively frequent sequel of the infectious diseases such as pneumonia scarlet fever meningitis measles and gonorrhea. It may be a complication of septicemias and osteomyelitis. Not infrequently no disease other than an acute respiratory infection may precede the onset of the joint lesion Pyogenic joints are known to follow furunculosis and cellulitis In some instances a *focus of origin cannot be found*

Organisms may gain access to the joint cavity by one of several avenues. Once *entrance has been achieved the response* of the joint is governed by the virulence of the organisms and the resistance of the patient. The most common mode of entry is through the blood stream although this may occur at any age it is observed most often in children. Penetration of the knee joint by contaminated missiles occurs frequently in combat open fractures communicating with the joint cavity may be a mode of entry for organisms As mentioned previously contamination of a joint cavity may occur during some operative procedure, the author has observed several such unfortunate complications. Finally the joint may be involved by direct extension of an infectious process in adjacent tissues. In the knee joint as in other joints primary implication of the femoral or the tibial epiphysis may occur the suppurative process may traverse the cancellous bone and the overlying cartilage to gain entrance to the joint cavity likewise an osteomyelitic focus in *the metaphysis may pierce the epiphyseal* plate and the epiphysis to reach the joint or it may extend along the undersurface of *the periosteum and ultimately under the* capsule to gain access to the joint cavity Osteomyelitis of the patella may be the source of pyogenic organisms *if the lesion* penetrates the cartilage and communicates with the joint cavity The author has recorded two such cases in Chapter 11, Affections of the Quadriceps Apparatus

PATHOLOGY

Following invasion of the joint cavity by organisms, the synovial membrane is the first structure to respond to the invaders The synovialis becomes hyperemic and pours into the joint cavity large quantities of a serous exudate which is essentially synovial fluid later there is a *pronounced* rise in the cell count the predominant cells being polymorphonuclear leukocytes the *protein count rises, and the fluid now be*comes turbid and thickened and assumes all the characteristics of pus. This stage of the *infection is designated as the purulent stage* while the earlier stage is the seropurulent As the process continues the joint capsule *is markedly distended with pus In fact* it may rupture into the surrounding tissues causing areas of local tissue necrosis which ultimately break through the skin to form sinuses.

Pus has a deleterious effect on the hyaline cartilage it causes liquefaction necrosis The work of Phemister reveals the mechanism of this process this observer points out that pus contains a proteolytic ferment protease which is derived from the dead neutrophils This substance is capable of dissolving the cartilage the cartilage at the points of continuous contact is affected first The extent of involvement of the cartilage is determined by the duration and the severity of the infection In the early stages chondrolysis is limited to the superficial stratum of articular cartilage which becomes fibrillated and loses its bluish-white glistening appearance but becomes roughened and opaque With further progression of the process it causes dissolution of all the cartilage it is interesting to note that the calcified stratum of cartilage is able to resist the chondrolytic action of the protease *it is the last barrier to be overcome*

The bone ends of an affected joint are involved only in fulminating suppurative processes of long duration In such instances all the cartilage is destroyed, and the subchondral bone is bathed in pus however, the bone has sufficient resistance to preclude the formation of bone abscesses or sequestri, these are indeed rare complications On the other hand, it is not infrequent in children to observe death of an epiphysis, particularly the capital femoral epiphysis resulting from complete destruction of its blood supply The author has opened several suppurative hip joints in which the capital epiphysis was found to be detached completely from the neck of the femur and constituted a loose body in the joint cavity A comparable situation never has been encountered in suppurative arthritis of the knee joint.

After the acute process is brought under control the acute inflammatory tissue begins to undergo maturation first forming granulation tissue which may supplant the greater portion of the synovialis By projecting over the articular surfaces the granulation tissue forms a pannus over each bone thereby establishing continuity between the opposing surfaces The basis for fibrous ankylosis of the affected joint is now laid down As maturation progresses the granulation tissue is converted into fibrous tissue producing adhesions of varying size and strength between the bony elements of the joint and obliterating the joint cavity During this process many areas of cartilage that have survived the chondrolytic action of the proteolytic ferment are destroyed by the granulation tissue which deprives the cartilage of any nutrient substances This process is further enhanced by granulation tissue growing from the marrow spaces in the subchondral bone which undermines and destroys the overlying articular cartilage As pointed out by Luck in his timely work *Bone and Joint Diseases* suppurative arthritis is one of the most common causes of ankylosis and the healing stage may terminate in one of three forms of ankylosis fibrous cartilaginous or osseous. Fibrous ankylosis results when the articular surfaces are bound together by firm adhesions formed by condensation of the interposing granulation tissue. Cartilaginous ankylosis may result from transformation of fibrous tissue to fibrocartilage in response to functional stresses or by the blending of opposing areas of affected articular cartilage. Bony ankylosis invariably follows complete destruction of the articular cartilage In the beginning the bone ends are bound together by dense fibrous tissue which is transformed later into bony trabeculae With increased function of the limb these trabeculae are replaced by lamellar bone

Fortunately not all cases of suppurative arthritis progress to the stage of ankylosis The disease may be controlled sufficiently early to preclude serious damage to the articular cartilage If function is restored early after the disease is controlled the fibrous tissue replacing portions of the synovialis affected may be converted into a smooth glistening surface which is covered by a layer of cells capable of producing synovial fluid this does not occur if ankylosis becomes established In some instances in spite of marked thinning and alterations of the articular cartilage a useful range of motion is salvaged In such knee joints however abnormalities of the cartilaginous and the osseous elements of the joint that are consistent with degenerative arthritis invariably occur

Clinical Manifestations

Sudden onset of a systemic reaction with fever chills and leukocytosis associated with involvement of a single joint presupposes a blood-stream infection Aspiration of pus from the affected joint establishes the diagnosis of pyogenic arthritis Smears, cultures and in some instances animal inoculations are essential to determine the identity of the responsible organism The

presence of foci in other parts of the body may provide a clue to the causative bacterium. Gonococci recovered from a purulent urethral or cervical discharge or from prostatic secretions may disclose the true nature of the suppurative process when *smears and cultures of the fluid recovered* from the joint fail to provide convincing *data to establish the correct diagnosis*

Frequently the knee joint is the seat of suppurative arthritis When involved in addition to the constitutional response mentioned previously the knee is swollen hot and painful usually it is held in varying degrees of flexion and both active and passive motion initiate excruciating pain Spasm of the flexor muscles resists any attempt to extend the joint the flexed position is further enhanced by the massive intra-articular effusion and pain In childhood pyogenic arthritis of the knee is relatively common it tends to run a fulminating course and in infants it may be difficult to establish the diagnosis Careful examination will disclose a swollen tender hot knee joint held constantly in partial flexion The joint lesion may be obscured by the severe systemic reaction the child is toxic and dehydrated and has a high fever and leukocytosis In children it is important to distinguish purulent arthritis from osteomyelitis of the lower end of the femur or the tibia In this condition the knee joint may show some swelling the knee is flexed and motion precipitates severe pain Also in children suppurative arthritis may be a complication of phlebitis resulting from intravenous procedures The author has encountered one such case which implicated the knee joint and resulted in amputation of the limb this was before the days of antibiotics

Suppurative arthritis of the knee joint must be distinguished from rheumatic fever rheumatoid arthritis osteomyelitis of the femur and the tibia tuberculous arthritis acute traumatic synovitis and traumatic hemarthrosis

Roentgenographic Features

Early in the disease the cartilaginous and the bony elements of the joint show no abnormalities However marked distention of the joint capsule and detectable swelling of the pericapsular tissues particularly the subcutaneous tissue is demonstrable, thus last feature is rarely observed in gonococci infection of the joint Decalcification is not usually apparent at this time, but some local decalcification may be discernible The joint space may be wider than that on the unaffected side As the process progresses to a later stage decalcification becomes more pronounced particularly in cases of gonococcic arthritis, and the joint space becomes narrowed as a result of destruction of the articular cartilage Narrowing is most marked at the opposing surfaces of the articular cartilage this is in contrast with the findings in tuberculous arthritis where these areas of the joint are implicated last. Varying degrees of marginal bone destruction may be observed again this is usually more pronounced where loss of the articular cartilage is extensive Sequestration due to massive necrosis is rarely seen except in the hip joint when the capital epiphysis undergoes avascular necrosis and is detached from the femoral neck however dislocation or subluxation may occur

During the healing stage calcification of the bone ends returns to normal the eroded *margins in the articular* cortex become more sharply defined and may appear to be more dense than the surrounding bone bony ankylosis may occur In healed cases of long standing bony alterations consistent with degenerative arthritis are manifest

Management

Too much emphasis cannot be laid on the importance of establishing an early diagnosis of pyogenic arthritis If adequate treatment is instituted early severe damage to the articular cartilage is prevented and a joint with excellent function can be antici

pated However, if the diagnosis is made late, irreparable damage is inflicted on the cartilage and the synovialis so that even with the most efficacious form of therapy varying degrees of dysfunction must be expected, and in some instances ankylosis of one form or another ensues The advantages of early aspiration of an infected joint are now generally understood The old fear of aspiration of joints for fear of introducing organisms into the joint cavity no longer prevails when the procedure is executed under strict aseptic technic. Early and properly performed aspiration provides joint fluid for bacteriologic examination It also reduces the intra articular tension thereby relieving pain In addition aspirations prevent the accumulation of large quantities of pus which, when under prolonged increased pressure cause destruction of the synovialis, lysis of the articular cartilage and stretching of the capsule and the ligamentous apparatus of the knee joint. It becomes apparent that proper timing is an essential factor in the treatment of pyogenic arthritis

In formulating a plan of therapy for suppurative arthritis one must understand that the articular manifestations comprise only one facet of a generalized systemic infection Except in cases of pyogenic arthritis resulting from penetrating wounds, the joint involvement is a complication of a blood-stream infection Hence general measures must be instituted to treat the patients systemically administration of repeated small blood transfusions (250 cc. of whole blood for adults and from 50 to 100 cc. for children) every 2 or 3 days if necessary, intravenous administration of fluids sodium potassium and chlorides to maintain a normal electrolyte balance a high protein diet and ascorbic acid relief of pain and apprehension by appropriate sedatives and specific treatment in the form of antibiotics and chemotherapy The form of local treatment is governed by the stage of the pyogenic process For practical purposes three stages must be considered acute, reparative and late

Acute Stage The aims in this stage are (1) to control infection (2) to prevent severe damage to the joint elements and (3) to restore normal function Too often we fall short of these goals Regardless of the type of pyogenic organism responsible for the suppurative process, conservative methods should be tried in the early stages of the disease The high intra articular tension should be relieved this is achieved best by repeated aspirations of the joint carried out daily or every second day, depending on the rapidity of re-formations of purulent material The technic of this procedure is described on page 498, adherence to strict aseptic precautions is essential With each aspiration penicillin is instilled directly into the joint In addition, penicillin is administered parenterally also, depending upon the organisms identified in the pus, various chemotherapeutic agents are given The author employs the following routine in the acute stage The joint is aspirated with a large bore needle, through the same needle 500 000 units of penicillin in 10 cc of normal saline is injected into the joint cavity In addition, 300,000 units of penicillin is given intramuscularly every 6 hours this is supplemented by sulfathiazole in staphylococcal arthritis and sulfadiazene in streptococcal and gonococcal arthritis In pneumococcal arthritis sulfonamide and penicillin are combined as described above This regimen is continued until the suppurative process is controlled as indicated by disappearance of the constitutional and the local manifestations As a rule this is achieved in 5 to 7 days, failure to note any subsidence in the condition within this period is an indication for surgical intervention.

During the execution of the aforementioned therapeutic program the affected limb should be at complete rest Traction to the lower leg is the most efficacious method it facilitates nursing care permits

traction previously applied to the lower leg of the affected limb and transfers the patient into a balanced suspension apparatus, using a Thomas splint with a Pearson attachment The patient is able to exercise the knee joint passively to any desired degree of flexion and extension This is achieved by means of a rope that is attached to the end of the Pearson attachment and passed through a series of pulleys to the head of the bed within the patient s reach Between the exercise periods the limb is suspended in the position of maximum extension Also, exercises of the quadriceps are instituted and performed conscientiously on a regulated regimen usually 10 minutes every 3 hours In the beginning the program should be under the supervision of a competent physical therapist. When power is restored sufficiently to the quadriceps to perform straight leg raising, elastic resistance is added and later the limb is made to work against progressively increasing loads In addition such measures as underwater exercises and the whirlpool bath tend to enhance restoration of motion Nonprotected weight bearing should not be permitted until the quadriceps is sufficiently strong to stabilize the joint and protect it from abnormal stresses incident to function and until powerful extension and flexion of the joint are achieved

During the reparative stage the author prefers the use of crutches to prevent full weight bearing and rarely employs knee cages or braces these tend to increase quadriceps atrophy The tendency toward development of flexion contractures is constant this is observed even after a relatively good range of active motion is attained As a prophylactic measure, long posterior molded plaster splints are worn during the night for 2 to 4 months after all evidence of activity in the joint has subsided and restoration of motion is progressing satisfactorily Moreover continuous traction to the lower leg during the acute and the reparative stages up to the time that exercises are started prevents the formation of serious flexion deformities Neglected cases invariably exhibit varying degrees of flexion contractures When encountered, the application of skin traction in the form of Buck's extension may suffice to eliminate the deformity If this method fails, the use of turnbuckle casts invariably achieves correction Great force must never be employed to attain correction such measures may reactivate the pyogenic process

Late Stage In this stage are found the devastating effects of a fulminating pyogenic process now completely extinguished The joints may show varying degrees of destruction of the articular surfaces, partial or complete restriction of motion, flexion deformities and in some cases bony ankylosis Now the problem at hand is one of rehabilitation of the patient by various surgical procedures which will provide the patient with a painless and useful limb If possible one should endeavor to restore a satisfactory range of motion, however, this is not always possible or advisable The surgical procedures most commonly employed are osteotomies for correction of deformities arthrodeses to achieve bony ankylosis and arthroplasties to restore motion these are discussed in detail in Chapter 13 Surgical Approaches and Procedures ' The following cases are typical examples of some of the problems encountered.

Case J M., male aged 20 years, was first seen on June 12, 1948 when he complained of pain and swelling of the left knee joint. At the age of 4 years the patient developed suppurative arthritis following whooping cough. The knee was not draining but was placed in a plaster cast for many months. As long as he could remember, the knee was "stiff' and became painful and swollen after any form of activity

Examination revealed a boggy swollen, painful knee with only 45° of flexion, there was a 10° flexion contracture of the joint. Roentgenographic study disclosed marked

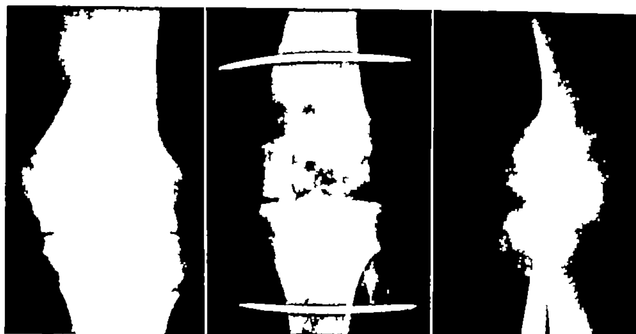


FIG 383 (*Left*) Left knee joint of a male 20 years old. This patient had a pyogenic infection at the age of 4 years Note the thin joint space and the moderate marginal lipping of the tibia only 45° of motion were demonstrable in the joint. (*Center*) Arthrodesis of the knee joint. Contact and compression between the raw surfaces of the femur and the tibia are maintained by the method depicted herein (*Right*) Solid bony ankylosis of the knee attained 4 months after the arthrodesing operation.

narrowing of the joint space and irregularity of the articular surfaces (Fig 383, *left*) The patient s occupation demanded long hours of standing because of the pain he was unable to hold a position for any length of time Arthrodesis of the joint was advised the patient refused the operation As a second choice synovectomy was recommended which was performed on July 14 1948 At the time of operation a markedly thickened synovial membrane was noted also the articular surfaces of the femur the tibia and the patella showed large areas denuded completely of cartilage Numerous marginal exostoses of varying size were present on the femur and the patella In addition to synovectomy the patella was excised and the exostoses were removed Three months after the operation the patient gained sufficient motion to permit complete extension of the joint his pain was decreased markedly

Two years later he returned complaining of severe pain although he had not lost any more motion He was now ready to have an arthrodesis of the joint which was performed on May 6 1950 The operative method employing elastic compression was performed (Fig 383 *center*) Figure 383 *right* depicts the result attained 4 months after operation This patient now has a painless, useful limb and when last examined (2 years after the arthrodesis) was very active employed and satisfied with the result

Case B K a female, 27 years old was first seen in July 1945 in a service hospital with a suppurative arthritis of the left knee joint in the reparative stage The causative organism was the gonococcus. In spite of intensive chemotherapy and antibiotic therapy the process went on to marked destruction of the joint. It must be admitted that data obtained at a later date disclosed that the above therapeutic measures were employed too late The lesion was diagnosed erroneously as rheumatic fever and was treated as such for several weeks Intensive physical therapy failed to give a useful range of painless motion On November 26 1946 she had constant pain and only 20 of motion Roentgenograms at this time revealed pronounced irregularity of the medial joint surfaces (Fig 384 *top*) In 1948 no change was demonstrable in the knee joint an arthroplasty was performed on June 25 1948 Figure 384 *bottom* depicts the knee joint 2 years after the arthroplasty She now

has approximately 70° of flexion good stability and no pain The joint is capable of meeting all her functional demands.

In the event that conservative measures fail to control an acute suppurative process within 5 to 7 days, or if a neglected case is seen after this period of time incision and drainage of the joint are mandatory These procedures are discussed in Chapter 13, "Surgical Approaches and Procedures" Prior to the advent of chemotherapeutic and antibiotic agents, cases were encoun

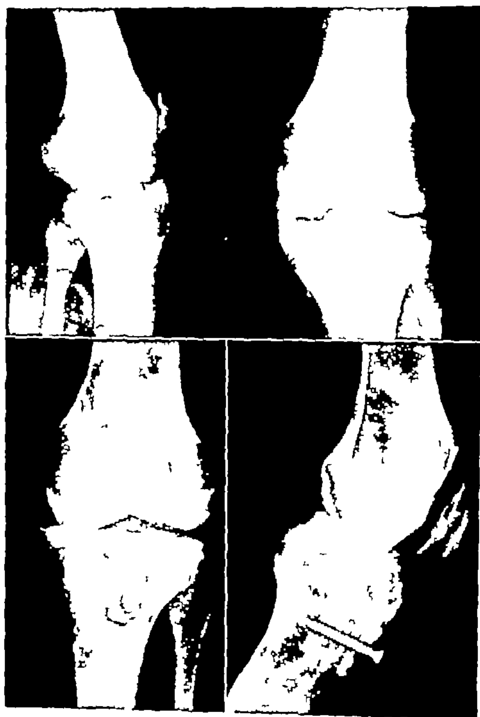


FIG 384 (*Top*) Destruction of the medial joint space following suppurative arthritis produced by gonococcal infection (*Bottom, left* and *right*) Roentgenograms of the above case 2 years after an arthroplasty of the affected knee joint. The joint has 70° of painless motion and excellent stability

tered occasionally which failed to respond to conservative measures or even to extensive incision and drainage In such instances amputation or resection were justified in order to save the patient s life At the present time occasionally cases are observed which are not controlled by conservative therapy and so necessitate radical incision and drainage of the joint but the author has not seen one case within the past 10 years in which amputation was justified. In some fulminating cases or some cases encountered late extensive articular damage occurs which precludes a satisfactory range of motion When such a situation becomes apparent the process should be allowed to go on to ankylosis of the joint the limb should be immobilized in the position of optimum function A stiff stable knee is far more serviceable than one with a few degrees of painful motion. Rarely are the bone ends implicated in the infectious process If such an event occurs, the problems of treatment are similar to those in osteomyelitis

Aspiration and Irrigation The technic of aspiration of the joint is described on *page 498* *Mention should be made of irrigation of the knee joint during the acute stage* Although the author has employed this method as described by Cotton on *several occasions he has not found it necessary* since the method of aspiration and instillation of penicillin into the joint has been popularized

Cotton s Technic Under local anesthesia a cannula or a small trocar is inserted on each side of the joint this is connected with a rubber tube attached to a douche can that is held at least 18 inches above the joint From 3 to 5 gallons of normal saline are allowed to flood the infected area first, the fluid is allowed to run into the joint until the articular capsule becomes distended next, the irrigation tip is detached and the fluid is allowed to run out this continues until the aforementioned volume of fluid is consumed The procedure is repeated on alternate days until constitutional and local symptoms have subsided. Penicillin may be instilled into the joint at the termination of each irrigation The after-care of the limb is similar to that described following treatment by aspiration. The author does not favor repeated irrigations as they minimize the bactericidal *power of the synovial fluid and deprive the* articular cartilage of nutrient materials

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13

Surgical Approaches and Procedures

GENERAL CONSIDERATIONS

Knowledge of the topographic anatomy and comprehension of the intricate functional mechanism of the knee joint is essential before one can perform with safety, surgical procedures in this region. Such information ensures the safety of vital structures in the field of operation, facilitates adequate exposure of the desired areas and guarantees restoration of maximum function. In general, whenever feasible, approaches to specific regions should be designed to avoid the pathways of important nerves, blood vessels and ligaments. In some instances, however, this is not possible. If such is the case, the structures should be visualized clearly and protected from injury during the course of the operation. This is particularly true when incisions are made in the posterior region of the knee joint.

Primarily, the functions of the knee joint are to allow free rhythmical locomotion and to provide stability for the lower limb. Because it occupies a position between the ankle and the hip joint, both possessing wide and diversified arcs of motions, the knee joint functions at a mechanical disadvantage. It is able to overcome this handicap by virtue of the configuration of its bony elements, its strong ligamentous apparatus and the powerful muscles which cross the anterior, posterior, medial and lateral aspects of the joint; the quadriceps apparatus plays a major role in attaining the functional requisites of this articulation. The goal of operative procedures in the region of the knee joint is to restore optimum painless function and stability. In order to achieve this goal, it becomes mandatory that the surgeon have an accurate evaluation of the role that each structure plays, singly or in combination with other structures, in the over-all performance of the knee joint. Furthermore, he must know the anatomic peculiarities of this region and the alterations that are compatible with good function. In the light of this information, certain modifications in the normal anatomy of the region are justifiable providing they do not preclude good function.

For example, it has been demonstrated clinically that removal of the patella does not impair seriously the efficiency of the *quadriceps apparatus*; hence, in selected cases it is a justifiable procedure. On the other hand, the protective nature of the patella to the anterior articular surfaces of the femoral condyles and its role in enhancing quadriceps power must not be underestimated, making it apparent that this structure must not be deleted indiscriminately. One peculiarity of this region is the rapidity with which the vasti muscles, particularly the vastus medialis, lose tone and volume after any form of trauma. All are aware of the seriousness of this undesirable sequel. It is responsible for varying degrees of instability of the knee joint and predisposes this articulation to intra-articular damage resulting in synovitis with effusion. It becomes apparent that, when possible, operations in this region must be designed to preserve the integrity of the quadriceps apparatus and to maintain or at least to restore rapidly volume and tone of the vasti muscles. Only in this manner can optimum function be restored in the shortest period possible. Fail

ure to respect the vulnerability of the quadriceps group of muscles will result in serious and protracted dysfunction of the knee joint

As a rule, operations on the knee are performed to correct some anatomic disorder or to remove disrupted or pathologic structures or tissues In these cases the surgeon has a definitive plan in mind and proceeds accordingly Not infrequently, however an accurate diagnosis cannot be made prior to surgery, yet exploration of the joint is indicated Occasionally the true nature of the pathologic abnormality is not ascertained until the affected region has been explored and visualized The aforementioned circumstances make it mandatory that the surgeon possess sufficient clinical experience and technical skill in surgery of this region to handle with dexterity all lesions encountered

PREOPERATIVE MANAGEMENT

It has been recorded previously that preservation of tone and volume of the vasti muscles is most essential in order to ensure normal function of the knee joint and to prevent sequelae capable of producing profound disability To attain this goal whenever it is possible treatment should begin before the affected extremity is subjected to surgery A carefully regulated and supervised regimen comprising rhythmic exercises of the quadriceps muscles, such as those described in the chapter dealing with disorders of the quadriceps apparatus is started at least 36 to 48 hours prior to operation Every effort must be made to impress the patient with the urgency of this preoperative management Once the patient has grasped the necessity of the exercises particularly the relationship that they bear to good function and rapid recovery he invariably gives his utmost co-operation Having mastered the exercises before operation most individuals have little difficulty in resuming them after surgery This is in great contrast with those cases in which no thought is given to the quadriceps muscles prior to operation. In many of these cases initiation of quadriceps drill after operation is a difficult feat, and in a few it is impossible

PREOPERATIVE PREPARATION OF LOCAL AREA

Numerous technics for preparation of the local area have been evolved in different clinics and hospitals All have stout supporters However, the truth is that by and large all are excellent technics if they are executed carefully in all details Certain precautions must be mentioned Strong chemical agents such as gasoline, benzene and iodine, if employed, should be used sparingly and removed carefully with alcohol or ether so that dermatitis does not follow and complicate the operative procedure this is particularly important in fair individuals. Preliminary scrubbing of the part with soap and water, as is done in many technics should be performed gently Not infrequently, the skin shows mechanical irritation resulting from the rough and enthusiastic efforts of an assistant or a nurse who desires to cleanse the area thoroughly Although it may appear to be superfluous the next precaution deserves mention Care should be used in shaving the operative and the adjacent regions Too frequently, these parts reveal numerous scratches and even patches of skin denuded of its superficial layers—the result of bearing down on a dull notched razor or of inexperience, lack of skill or carelessness in the use of a sharp blade.

The following technic is preferred by the writer From 12 to 24 hours prior to operation the extremity is shaved carefully from the groin to above the malleoli The next steps in the technic are performed under sterile precautions the nurse puts on sterile gloves and uses sterile instruments from a tray set up especially for this phase of the preparation of the part. First, the skin is

cleansed gently with tincture of green soap using sterile cotton balls instead of gauze pads this tends to minimize mechanical irritation of the skin Next, the soap is washed away with sterile water, this is followed by the application of one coat of 2 per cent tincture of iodine which is removed with a solution of 70 per cent alcohol Finally the entire extremity is sponged with ether and wrapped in sterile towels

Immediately prior to operation after the patient has been anesthetized an Esmarch bandage is applied over the outer dressings from the toes to the middle of the thigh A pneumatic tourniquet is applied proximal to the Esmarch bandage and inflated to 300 mm then the Esmarch bandage and the dressings around the leg are removed Two coats of 1 1 000 tincture of benzalkonium chloride (Zephiran) are applied from the groin to above the malleoli The last step comprises enclosing the entire limb in sterile stockinette rolled on from the toes and reaching as far as the groin A sandbag wrapped in a small sterile sheet is placed under the knee it is large enough to flex the knee about 30° If the operation to be performed is on the posterior aspect of the knee joint the limb is prepared in the same manner but the patient is placed in the prone position with the extremity extended

Although the incision should be adequately large to ensure free accessibility to the desired region unduly large incisions are to be condemned The skin incision is made through the stockinette With another scalpel the skin flaps are carefully mobilized for a short distance The cut edges of the stockinette are drawn over the skin margins and clipped in place by Michel clips

Position of the Limb

The position of the limb varies with different surgeons When it is desired to expose the semilunar cartilages and the cruciate ligaments some prefer the leg to be flexed 90° believing that this position provides the best exposure of the intra-articular structures and of the articulating surface of the tibial plateau Others perform the same procedures with the limb flexed from 20° to 30° depending upon an assistant to rotate and adduct or abduct the lower leg during the operation The writer prefers the former position Each surgeon should choose that position which he believes facilitates for him to the utmost the performance of the operation in question.

MANAGEMENT OF TISSUES

It is essential to carry out surgical procedures with precision and rapidity Undue exposure of tissues favors air contamination and subjects tissue to mechanical trauma resulting from continued retraction At all times the soft tissues must be handled gently sharp dissection is to be preferred to blunt dissection and crushing of soft tissues must be avoided The use of dry gauze sponges in the wound adds further insults to the tissues Observance of these elementary surgical principles minimizes the incidence of postoperative surgical complications and favors primary healing of the wound Failure to observe them may result in pronounced and persistent postoperative effusion, hemarthrosis and even sepsis.

Hemostasis can be achieved by a well applied tourniquet However when large vessels are encountered and severed the ends are ligated by fine cotton ligatures. This ensures against bleeding after the tourniquet is removed When ligatures are employed they should be placed so that they include only the severed ends of the vessels or only as little of the surrounding tissues as possible the ligatures are cut close to the surgical knot in order to minimize the amount of foreign material in the wound

Foreign materials in the wound or in the joint are sources of irritation and not conducive to rapid primary healing Bone particles and fragments of articular cartilage act in a similar manner When the operative procedure necessitates drilling of bone bone spicules and particles are disseminated throughout the soft tissues and into the

joint. In such instances the region to be drilled is isolated from the adjacent tissues by wet sterile sponges to which the bone particles adhere, this facilitates their removal At the completion of the work on the bone and before the wound is closed, the joint and the soft tissues are flushed gently with warm, sterile, normal saline solution.

CLOSURE OF WOUND

Accurate closure of the edges of the wound ensures primary healing However suture materials like other foreign materials should be used sparingly, yet the strength and the number of sutures should not be sacrificed to the extent that wound closure is inadequate The writer prefers the use of No. 30 cotton sutures It is not essential to close the wound in layers Incisions made in the anterior the medial and the lateral aspects of the knee, the edges of the outer fascia the capsule and the synovial membrane are approximated by interrupted sutures so placed that the sutures do not penetrate the inner surface of the synovial membrane The skin is closed with interrupted sutures of the same material

DRESSINGS

After operation and before release of the tourniquet, a properly applied pressure bandage maintains hemostasis. Compression of the part must be uniform and such that it ensures hemostasis but does not obstruct the circulation. Not infrequently a dressing applied too tightly causes swelling of the limb below the knee and severe pain in the operative region and joint this is particularly true if the entire limb is not enclosed in the compression bandage The following dressing is used by the writer 2 sterile gauze pads are laid directly over the incision 2 or 3 layers of cotton surround the limb from mid thigh to the middle of the lower leg the entire limb is enclosed in an elastic bandage 3 inches wide, extending from the toes to the middle of the thigh It is so applied that snug uniform compression is made on the entire limb Finally the tourniquet is removed

ANESTHESIA

The choice of anesthesia is governed by the operation to be performed, the physical status and the age of the patient, as well as the anticipated duration of the operation. In general, intravenous Pentothal Sodium when not contraindicated, is an excellent anesthetic agent Spinal anesthesia induced by a single injection or by continuous administration of the anesthetic agent, depending upon the duration of the operation, is preferred by some men particularly when handling patients in the younger age groups, such as are found in military hospitals Intratracheal anesthesia is by far the most desirable anesthesia when the patient must assume the prone position on the operating table It eliminates the many and customary difficulties encountered with routine inhalation anesthesia

SEPSIS

Fortunately, the undesirable and tragic complication of sepsis following surgery on the knee joint is encountered less frequently than in former years When it does occur it is usually the result of faulty aseptic technic or poor surgical judgment however it may arise from implantation into the operative area of micro-organisms by way of the blood stream from a focus elsewhere in the body Although the incidence of this sequel is small its possibility should be constantly in the minds of surgeons and no precautions should be disregarded which will minimize its occurrence For this reason the writer injects 10 cc. of penicillin (250 units per cc.) into the knee joint and over the wound edge after operation It is a valuable adjunct as a prophylactic agent and adds to the defense against infection More important than the administration of antibiotics prophylactically is the observance of the surgical principles mentioned previously particularly those dealing with gentle manipulation of

soft tissues avoidance of prolonged and forceful retraction and meticulous aseptic technic.

Should such a complication supervene the patient discloses both constitutional and local manifestations Generally the onset is sudden and the character of the symptoms is severe The patient reveals evidence of *toxic absorption manifested by hyperpyrexia* dehydration, hypoproteinemia and loss of body weight Locally the capsule of the knee joint becomes greatly distended and the periarticular tissues exhibit increased local temperature Pain is constant and it is accentuated by the slightest movement of the joint surfaces.

Treatment should be directed toward eradication of the infection and restoration of the normal physiology of the patient Local treatment comprises daily aspiration of the joint and the injection of penicillin solution (250 units per cc) into the joint cavity In addition systematic administration of penicillin singly or in combination with other antibiotics such as aureomycin is carried out It is important to identify and culture the offending organism obtained at *the first aspiration also the susceptibility* of the organism to penicillin and other antibiotics should be determined at this time Such a regimen is continued until the infection is controlled as evidenced by improvement in the general condition of the patient return of the temperature to normal levels and subsidence of pain and swelling of the joint During this period considerable comfort may be afforded the patient by applying traction to the extremity below the knee from 3 to 5 pounds is sufficient The general condition of the patient is improved by administering adequate amounts of fluid by the intravenous route if necessary and by maintaining at all times the electrolytes in balance Small transfusions of whole blood given at *frequent intervals are valuable* adjuncts in restoring normal protein levels combating anemia and supplying needed antibodies and buffer substances Under such management the necessity of open drainage of the joint is minimized

ANATOMIC CONSIDERATIONS

In Chapter 3 "Normal Anatomy of the Knee Joint the anatomy of this region was dealt with in detail. However in order to *facilitate* comprehension of the numerous surgical approaches to this articulation some of the more pertinent anatomic features will be reviewed briefly

Bony Elements

The bony components of the knee joint comprise the condyles of the femur the tuberosities of the tibia and the patella In spite of the fact that it is the largest joint in the body, its bony configuration is such that it provides little toward stability *Strength and stability are provided by the* surrounding soft tissue elements that comprise the muscular apparatus motorizing the joint the capsule and the ligamentous structures

Capsule

Unlike *most of* the joints of the extremities the articular cavity of the knee joint is not enclosed completely by a distinct fibrous capsule Dissection of several hundred knee joints failed to disclose even in a single instance a *well-defined capsule on the anterior* aspect of the joint In this region the articular cavity is limited by the aponeurosis of the vasti the fascia lata the iliotibial band the quadriceps tendon the articular surface of the patella and the patellar tendon This *is in contradistinction to the synovial membrane* in this region which in all instances is a very prominent structure On the posterior aspect of the joint the capsule is a stout fibrous structure extending from the proximal margins of the articular surfaces *of the femoral condyles and* the intracondylar line to the posterior border of the tibial plateaus Posteriorly the capsule i reinforced by a fibrous expansion from the

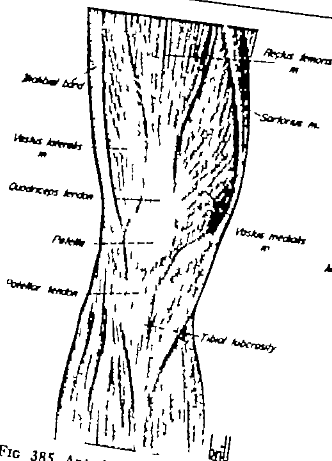


FIG 385 Anterior aspect of the knee joint the distal third of the thigh and the proximal third of the leg showing the landmarks of this region and the anatomic arrangement of the superficial components of the quadriceps muscle. The thigh and the knee are invested in the fascia lata.

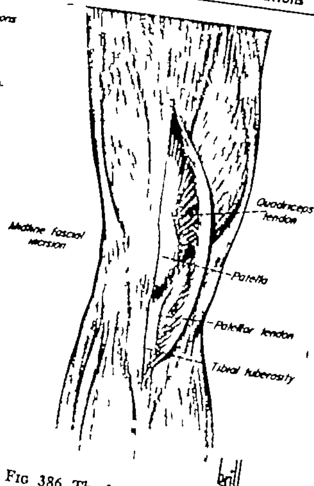


FIG 386 The fascia lata has been reflected from the anteromedial aspect of the knee Note that the superficial layer of the aponeurosis of the vastus medialis extends across the patella and blends with the aponeurosis of the vastus lateralis.

tendon of the semimembranosus which is directed upward and lateralward and is designated the oblique popliteal ligament. Medially the capsule is strengthened by the tibial collateral ligament fusing with the posterior oblique fibers of the ligament and the deep portions of the ligament (Figs. 32 33 37) As recorded previously the superficial fibers of the vertical and the anterior portion of the tibial collateral ligament does not fuse with the capsule Between the two structures a bursa often intervenes if not the interval contains areolar tissue Laterally the fibrous capsule is strengthened by both layers of the fibular collateral ligament which is separated from the lateral meniscus by the tendon of the popliteus muscle and its synovial sheath (Fig 37)

TENDON OF THE QUADRICEPS FEMORIS

The quadriceps tendon comprises 3 distinct laminae (Fig 18) The superficial layer consists of the tendon of the rectus femoris, the deep tendon of the vastus intermedius and the intermediate the tendons of the vastus lateralis and medialis At the lower end of the thigh the 3 strata blend to form a stout single structure which inserts into the superior and the lateral margins of the patella some fibers pass directly downward over the front of the patella and are continuous with the fibers of the patellar ligament. Some of the tendon fibers of the vastus lateralis and medialis form a broad aponeurosis on either side of the patella which occupies a position between the collateral ligaments and the corresponding

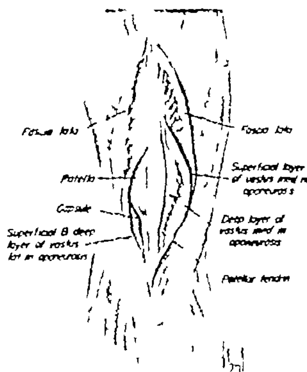


Fig. 387 Note the 2 layers of the aponeurosis of the vastus medialis and their sites of insertion The superficial layer is continuous with the deep fascia of the leg whereas the deep layer inserts into the medial margin of the patella and into the proximal border of the inner tibial tuberosity

borders of the patella and the patellar tendon (Fig 19) As pointed out by Abbott and Carpenter the aponeurosis of the vastus medialis covers the anteromedial aspect of the knee joint and divides into 2 layers superficial and deep The superficial layer is projected across the anterior surface of the patella and the patellar tendon and blends with the aponeurosis of the vastus lateralis distal to the tibial tubercle it fuses with the deep fascia of the leg The deep layer of the aponeurosis inserts into the medial margin of the patella and the proximal border of the inner tibial tuberosity On the anterolateral aspect of the knee joint the aponeurosis of the vastus lateralis fuses firmly with the deep fascia and inserts into the lateral margin of the patella and the proximal border of the outer tibial tuberosity It also blends with the iliotibial band

Directly beneath the aforementioned aponeurosis lies the synovial lining of the joint (Figs 385, 386 387)

Synovialis

As recorded previously the synovialis arises from the superficial cells of the structures destined to be the capsule and the intracapsular components of the joint This is achieved by a process of rearrangement of the cells rather than by differentiation, and the membrane appears after the development of the menisci the cruciate ligaments and the capsule In the light of this information it becomes apparent that the cruciate ligaments are not extrasynovial in the sense that they arise as extra-articular structures and later migrate into the joint carrying with them a reflected layer of synovial membrane In the adult joint the cruciates like the infrapatellar fat pad are excluded from the joint cavity by the synovialis but nevertheless are intracapsular structures like the membrane itself

The synovialis lines the posterior and the lateral portions of the fibrous capsule Anteriorly where the capsule is deficient it is projected upward on the anterior surface of the femur under the quadriceps muscle as a well-defined pouch which as a rule communicates with the suprapatellar bursa (Fig 43) The articularis genu muscle which lies under the cover of the vastus intermedius inserts into the proximal aspect of the pouch By this arrangement the synovial membrane is drawn upward when the leg is extended From its posterior region the synovia gives off several prolongations which have clinical significance One such projection envelops the tendon of the popliteus muscle forming a cul-de sac in this region occasionally it is continuous with the joint cavity of the upper tibiofibular joint Another is found on the posterior and the medial aspects and communicates in many instances with the relatively large bursa found constantly between the tendon of the semimembranosus and the medial

head of the gastrocnemius. A thick prolongation is found between the lateral condyle and the tendon of origin of the lateral head of the gastrocnemius muscle. Anteriorly, a pad of fatty tissue, varying in size and roughly pyramidal in shape, lies in the interval distal to the apex of the patella and the upper anterior border of the tibia in front of the intercondyloid eminences of the tibia. This fatty mass has a medial and lateral extension, semilunar pads, which project into the joint cavity and act as buffers for the femoral condyles when the joint is in a position of extension and hyperextension It is covered by synovialis, making it extrasynovial but intra articular

From the central portion or body of the infrapatellar fat pad a delicate fold of synovial tissue ligamentum mucosum, arises and proceeds upward and posteriorly to gain attachment on the intercondylar notch of the femur immediately in front of the femoral attachment of the anterior cruciate ligament. The cruciate ligaments are the most important structures in the posterior region of the joint. In some instances only the anterior and the lateral aspects of the posterior cruciate are covered with synovial membrane the posterior surface being in close contact with the fibrous capsule in other instances the entire ligament is enveloped by the membrane. The anterior cruciate is always enclosed completely by synovialis These structures like the infrapatellar fat pad are extrasynovial but are intra articular

Bursae

Bursae in the region of the knee joint are considered in detail in Chapter 3 Normal Anatomy of the Knee Joint' (Fig 45) For the sake of emphasis only the ones having important clinical and surgical significance will be discussed in this section Three bursae are found constantly in the anterior aspect of the knee they are the prepatellar bursa and the superficial and the deep infrapatellar bursa The prepatellar bursa occupies a position immediately under skin overlying the anterior surface of the patella, the superficial infrapatellar surface lies between the skin and the anterior surface of the tendon of the patella, the deep infrapatellar bursa is located on the anterior surface of the tibia under cover of the patellar tendon. On the medial and the posteromedial aspects of the knee joint, 3 important bursae are encountered constantly (1) the medial gastrocnemius bursa, situated between the medial tendon of origin of the gastrocnemius muscle and the tendon of the semimembranosis which frequently connects with the articular cavity of the knee joint (2) the semimembranosus bursa located immediately beneath the tendon of the semimembranosus muscle at its point of insertion into the tuberosity of the tibia, and (3) a bursa placed between the tendons of the sartorius gracilis, and the semitendinosus muscles and the outer surface of the tibial collateral ligament. On the lateral and the posterolateral aspects of the knee joint 4 bursae are present (1) the lateral gastrocnemius bursa, placed between the lateral tendon of origin of the gastrocnemius muscle and the fibrous capsule (2) a bursa situated between the tendon of the biceps femoris muscle and the fibular collateral ligament (3) a small bursa between the fibular collateral ligament and the tendon of the popliteus muscle and (4) a bursa between the tendon of the popliteus muscle and the lateral condyle of the femur As noted previously, the last bursa mentioned is really a prolongation of the synovial lining of the knee joint on the popliteus tendon forming a cul-de-sac in this region It was noted in the specimens studied in the investigation on the mechanics of the knee joint that frequently a bursa was encountered between the superficial anterior portion of the tibial collateral ligament and the deep layer of the ligament which is continuous with the periphery of the meniscus The bursa occupied a position opposite the meniscus, or inferior to the meniscus, between the tibial collateral liga

ment and the fibrous capsule or between the superficial anterior fibers of the tibial collateral ligament and the shaft of the tibia this was encountered relatively frequently These observations substantiate those of Brantigan and Voshell who also described a bursa distal to the meniscus and one between the tibial collateral ligament and the capsule

Arteries

Knowledge of the location and the course of the main arteries forming the arterial network around the knee joint is essential to avoid unnecessary division of these vessels during operative procedure in this region or if their severance is necessary to facilitate their exposure (Figs. 36 and 50)

A rich arterial network exists around the knee joint and supplies blood both to the superficial and the deep extra articular structures and also to the intra articular elements of the joint Two well-defined anastomoses arising from 3 arterial arches are discernible—a superficial and a deep the former is located at the level of the upper pole of the patella its vessels lie between the superficial fibers of the quadriceps muscle the latter lies below the level of the patella and is formed by 2 deep arches traversing the infrapatellar fat pad beneath the patellar tendon The arterial arches are formed by the terminal branches of the 4 genicular arteries the highest genicular (Genus suprema) the descending branch of the lateral femoral circumflex and the anterior recurrent tibial artery The 2 superior genicular arteries—medial and lateral—are given off from the popliteal artery at the level of the femoral condyles and proceed around the inner and the outer aspects of the femur under cover of the hamstring muscles They pass through the inner and the outer intermuscular septa respectively and continue anteriorly to the vastus medialis and the vastus lateralis where they anastomose with each other and with the highest genicular the descending branch of the lateral femoral circumflex and the inferior genicular arteries. The inferior medial and lateral genicular arteries are given off from the popliteal artery immediately below the distal margin of the oblique popliteal ligament They wind around the bone under cover of the tibial and the fibular collateral ligaments to reach the anterior aspect of the joint where beneath the patellar ligament they anastomose with each other and with the superior genicular arteries thereby completing the arterial network on the anterior margin of the knee joint The azygos genicular (middle genicular) artery arises from the posterior aspect of the popliteal artery It is smaller than the other 4 genicular arteries and together with the articular branch of the obturator nerve pierces the popliteal ligament to reach the joint cavity It is distributed to the synovial membrane the infrapatellar fat pad and the cruciate ligaments

Cutaneous Nerves

All aspects of the integument investing the knee joint are amply supplied by sensory nerves (Fig 52) Knowledge of the topographic anatomy of these structures is mandatory in order to avoid division of the nerves during operative procedures Severance of the cutaneous nerves particularly in the anteromedial region of the knee joint may give rise to unpleasant areas of anesthesia or paresthesia in the cutaneous distribution of the nerve distal to its point of division Occasionally painful neuromata develop in the divided proximal end of the nerve which may be sources of considerable annoyance and discomfort Occasionally as a result of direct injury to the nerves or constriction of the nerves in scar tissue numbness pain and paresthesia ensue in the cutaneous fields supplied by the affected nerve this unpleasant sequel is known a meralgia paresthetica which is encountered most frequently in lesions of the lateral cutaneous nerves and its branches

The cutaneous nerves distributed to the

skin around the knee joint are the anterior division of the lateral femoral cutaneous nerve of the thigh, the intermediate cutaneous nerve of the thigh and the saphenous nerve, both being branches of the femoral nerve, the infrapatellar nerve, a branch of the saphenous nerve the anterior and the posterior branches of the medial or internal cutaneous nerve which is also a branch of the femoral nerve the terminal branches of the posterior femoral cutaneous nerve which arises from the anterior divisions of the first three sacral nerves the lateral cutaneous nerve of the calf, a branch of the common peroneal the peroneal anastomatic nerve of the leg a terminal branch of the lateral cutaneous nerve of the leg, and the medial cutaneous nerve of the calf, the cutaneous branch of the tibial (internal popliteal) nerve The terminal filaments of the branches of the femoral nerve which are distributed to the skin of the anterior aspect of the knee joint form an interesting nerve plexus the patellar plexus.

HISTORICAL REVIEW OF SURGICAL APPROACHES TO THE KNEE JOINT

The numerous surgical approaches to the knee joint in common use at the present time evolved from a desire on the part of workers interested in the disorders of this articulation to eradicate the causative factors responsible for a large group of lesions all of which possessed a common denominator namely persistent or recurrent instability of the joint. As early as the fifteenth century Paré was cognizant of the fact that in some instances osteochondral bodies or joint mice lying free in the joint were responsible for the disabling syndrome Later Monro expressed the opinion that these loose bodies might originate from the articulating cartilage of the joint As a general rule these cases in the days of the aforementioned observers, were treated by manipulative methods practiced by bone setters who were prevalent in this period Stimulated by the work of Goodsir and Hunter, William Hey, a surgeon of Leeds, came to the conclusion that the menisci in many instances were the etiologic factors responsible for recurrent instability of the knee joint In his writings he recorded the pathologic changes noted in joints so affected and emphasized in particular the abnormalities of the semilunar cartilages these comprised fractures and displacement of the menisci In 1784 for the first time the designation internal derangement" of the knee joint appeared in a publication written by Hey He also recommended and described a manipulative method for the treatment of derangements of the menisci causing locking of the joint—a method which was used until the last decades of the nineteenth century For loose bodies he favored prolonged immobilization of the extremity Interest in the lesions of the knee joint was stimulated further by the meticulous investigations of the Weber brothers of Göttingen and Leipzig (1886) and of Meyer of Zurich (1873) who were concerned primarily with the functional mechanism of the individual components of the knee joint Meyer was the first to focus our attention on the peculiarities of the condyles of the femur and described the mechanics of the 'screw movement" of the knee joint when the leg is extended fully from a position of flexion

The work of the aforementioned observers, together with that of other notable contributors, as Hugh Owen Thomas and Hood prompted surgical intervention for the correction of noninfective and traumatic disorders of the knee joint In spite of the knowledge that Paré as early as the sixteenth century had attempted surgical removal of loose bodies in the knee joint, the hazards associated with any surgical procedure on an articulation comprised stanch barriers to surgeons of this period The chief obstacles were lack of anesthetic agents and the high incidence of postoperative infections following all operations Nevertheless during the last decades of the nineteenth

century, courageous surgeons began to attack the problem from a surgical viewpoint in 1866 Brodhurst removed a meniscus from the left knee joint Arthrotomy was popularized by Thomas Annandale of Edinburgh when he published two articles one in 1879 and the other in 1885 they were "Care of Loose Cartilages Recovered from the Knee Joint by Direct Incision with Antiseptic Precautions and Excision of the Internal *Semilunar Cartilage Resulting in a Perfect* Restoration of the Joint Movement From the time of the first operation of Brodhurst in 1866 to 1900 excision of the menisci rapidly gained favor in Europe through the efforts of Lauenstein and Bruns in Germany Giordano in Italy and Braquehave and March in France In the United States Goldthwait assured the American surgeons of the feasibility of arthrotomy in his articles "Knee Joint Surgery for Nontuberculous Conditions (1900) and Slipping or Current Dislocation of the Patella" (1904) During the first decades of the twentieth century a forceful wave of enthusiasm swept through the surgical clinics in Europe and America resulting in the designing of numerous anatomic approaches to the knee joint and ingenious surgical technics for the excision and the repair or reconstruction of disrupted soft tissue elements of the knee joint Many of these approaches and technics have weathered the test of time and the critical analysis that comes with end-result studies many are still popular today Some of them have been modified but their basic principles remain the same others have been discarded because of their impracticability *The anteromedial and anterolateral* incisions of Sir Robert Jones in the Liverpool clinic provide sufficient exposure to excise the menisci without opening the joint widely Many modifications of this incision have been designed Timbrell Fisher (1926) changed the obliquity of the incision but otherwise it is essentially the same Jones approach replaced in a measure the J" incision devised by Kocher Kocher (1894) also described a lateral parapatellar incision in which the patellar ligament remained intact von Langenbeck (1878) designed a semilunar medial parapatellar incision These provided the basic principles upon which Krida (1925) devised his parapatellar or general utility incisions whose popularity rapidly gained prominence

The U incision of Putti (1921) provides excellent visualization of the inside of the knee joint but it sacrifices the integrity of the patellar ligament which is severed in order to allow upward reflection of the patella Although this approach is seldom used for excision of menisci or reconstruction and repair of the cruciate ligaments it is a favorite approach for arthrodesis of the knee joint

The success achieved by the various anterior approaches to the knee joint for the removal of pathologic menisci stimulated surgeons to investigate other regions of the knee joint and to devise reconstructive technics for repair or replacement of the cruciate and the collateral ligaments New posterior incisions were devised or old ones were modified Brackett and Osgood (1911) published the description of a posterior incision for the removal of joint mice in the posterior capsule of the knee joint Putti (1921) and Henderson (1928) also described approaches to the posterior region of the knee joint Operations for reconstruction of the cruciate ligaments were first popularized by Hey Groves (1917) His methods were modified by Campbell Carell Callie and Le Mesurier Reconstruction of the collateral ligaments also began to gain favor and in 1924 Edwards worked out an ingenious technic for repair of the collateral ligaments using fascia lata and a portion of the biceps tendon to repair the lateral ligament A method of release of flexion contractures of the knee joint by a posterior capsulotomy was devised by Wilson (1929)

With the acquisition of refinement in aseptic technics and the attainment of skill in the handling of the bony and the soft

tissue elements of joints, surgery of the knee joint made rapid strides Chemotherapy and antibiotics add even a greater impetus to surgical investigation of all joints Other pathologic processes of the various elements of the knee joint other than those affecting the menisci, the cruciate and the collateral ligaments were subjected to closer scrutiny and surgical methods for their correction were devised One of the problems under consideration was recurrent dislocation of the patella This entity was attacked from a surgical viewpoint as early as 1850 when Heller, according to Huebscher, attempted to correct the disorder by scarifying the medial aspect of the joint capsule, hoping to cause sufficient contracture of tissues to prevent displacement of the patella to the outer side Hoffa (1890) advanced reefing of the tissues on the medial side of the patella Goldthwait (1904) created a check rein against lateral dislocation by transplanting the outer one half of the patellar ligament to the inner aspect of the tibia, and in 1930 Hauser recommended the transplantation of the entire patellar tendon with its bony insertion to the inner aspect of the tibia Other surgeons developed different approaches to this problem Realizing that developmental malformation of the lateral condyle of the femur was one of the reasons for recurrent lateral dislocation of the patella Robert Jones elevated the lateral femoral condyle by doing an osteotomy through the base of the condyle in the coronal plane and then prying it forward Later Albee attempted retaining the elevated anterior portion of the split condyle in place by inserting a bone graft between the two segments More recently ablation of the patella is gaining favor in some quarters for recurrent dislocations Excision of the patella for other reasons than recurrent dislocation was reported as early as 1860 by Putz of Strasbourg and in 1902 Joachimsthal reported a case of congenital absence of the patella with normal joint function Encouraged by Putz s work Murphy, in the United States, excised the patella for tuberculosis of that bone, while Heineck at about the same time reported a series of patellectomies, some of which were performed because of severe comminution of the bone For a while patellectomy was seldom performed until the subject was reopened by Brooke in 1936, who was of the opinion that this bone was in the process of phylogenetic reduction, a view with which the author is not in accord His work and enthusiasm initiated renewed interest in disorders of the patella and brought to prominence patellectomy for many lesions, such as recurrent dislocations fractures and osteoarthritis However this problem needs re-evaluation because it is becoming progressively more apparent that, in many instances, ablation of the patella is being practiced needlessly

SURGICAL APPROACHES TO THE ANTERIOR REGION OF THE KNEE JOINT

Landmarks

Knowledge of the topographic anatomy of this region is essential in order to facilitate operative approaches and to recognize deviations from the normal which may be present (Fig 388) In general, the bony components are relatively prominent structures and any abnormal alterations are apprehended readily Different degrees of flexion and extension of the joint produce a shift in position of the landmarks, making it necessary to be familiar with the location of the landmarks with the various positions of the joint The only constant feature is the distance between the apex of the patella and the insertion of the ligament of the patella into the tibial tuberosity the inelasticity of the patellar tendon makes this a constant interval regardless of the position of the joint As noted previously the extended knee joint possesses a normal valgity of 10° to 12° corresponding to the axial deviation between the tibia and the femur Although this angle varies slightly in different

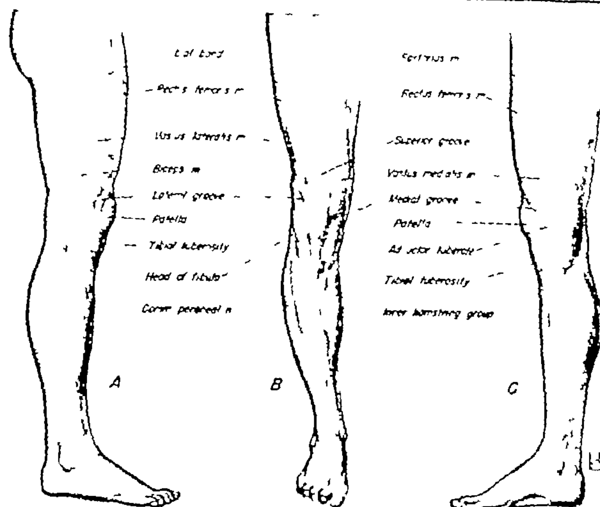


FIG. 388 Landmarks on the anterior anteromedial and the anterolateral aspects of the knee joint.

individuals marked variance, either in the way of an increase or a decrease of the angle is consistent with pathologic alterations as genu valgum or genu varum As a rule the normal deviation is greater in females than in males

On the anterior aspect of the knee joint the patella stands out as a prominent bony mass the configuration being detected readily by inspection and palpation With the knee extended and the quadriceps relaxed this bony mass can be displaced with ease upward downward and to either side Extending proximally from the base of the patella the tendon of the rectus femoris muscle is readily discernible the same is true of the patellar tendon which extends from the apex of the patella to the tibial tuberosity The length of the patellar ligament is approximately 5 cm , its mid-point lies opposite the joint line In the presence of a large effusion in the knee joint the mobility of the patella is increased greatly and ballottement of this bone can be demonstrated by tapping it gently this maneuver causes the patella to strike the anterior surface of the femur with each tap of the finger the contact can be both felt and heard

In the intervals between the lateral margins of the patella and the corresponding femoral condyles a distinct furrow is present running parallel with the patellar border In thin individuals the furrows are deep and well demarcated while in individual with large quantities of subcutaneous fat

they may be shallow or obliterated Another depression is discernible above the base of the patella connecting the two lateral furrows and producing a horseshoe-shaped peripatellar furrow (*Fig 388*) The grooves parallel the upper and the lateral boundaries of the suprapatellar pouch. In knee joints distended with blood or an effusion, the peripatellar furrows are ballooned out to form semicircular convexity around the lateral margins and the base of the patella. As recorded previously the patella is freely movable with the knee extended, by displacing the patella laterally or medially the corresponding borders of the condyles of the femur can be palpated.

When flexion of the knee joint is initiated the patella stands out as a prominent bony structure in the anterior aspect of the joint As flexion continues the patella becomes less prominent and more fixed in full flexion it lies deeply in the intercondylar notch of the femur and then no lateral motion is demonstrable, the apex of the patella lies opposite the joint lines, and the articular surface of the intercondylar notch is palpable immediately proximal to its base

Below the apex of the patella and on either side of the patellar ligament the pyramidal infrapatellar fat pad produces a soft fullness which becomes more prominent and tense when the quadriceps muscle is contracted with the knee fully flexed the fullness on either side of the patellar ligament is accentuated but remains soft On either side of the patellar ligament the joint between the femoral condyles and the tibia is readily palpable this is particularly true when the knee is in a flexed position In the region of the collateral ligaments the joint line is barely distinguishable because it lies under cover of these structures

On the lateral aspect of the joint several pertinent structures must be considered The enlarged anterior portion of the lateral condyle of the femur lies slightly in front of and proximal to the head of the fibula this feature is demonstrated best when the knee is flexed. The biceps tendon is readily palpable as it approaches its site of insertion into the head of the fibula The common peroneal nerve descends along the lateral side of the popliteal fossa in relation to the inner border of the biceps femoris muscle At the level of the superior border of the head of the fibula it becomes superficial and then proceeds to wind around the neck of the fibula lying between the peroneus longus muscle and the bone. In thin individuals the nerve can be palpated as it winds around the neck of the fibula.

On the medial aspect of the knee joint the most prominent structure is the medial femoral condyle, which is readily palpable The upper and inner boundary of this condyle ends in the adductor tubercle into which inserts the tendon of the adductus magnus muscle This tubercle lies on a line with the distal epiphyseal plate of the femur it is slightly proximal to the upper limits of the articular surface of the trochlea of the femur In their course downward the sartorius and the gracilis muscles wind around the posteromedial aspect of the condyle and then proceed forward to reach the medial aspect of the upper end of the tibia they are in relation to the semitendinosus and the semimembranosus (Fig 395)

On the anterior aspect of the knee joint with the leg extended actively the tendon of the rectus femoris muscle stands out prominently and its lateral borders are readily detectable The bulge of the vasti muscle on either side of the tendon of the rectus femoris is plainly visible The prominence of the vastus lateralis is at a much higher level and is less pronounced than that of the vastus medialis (Fig 388) In active extension of the leg a deep groove is present distal to the prominence of the vastus lateralis between the tendon of the rectus femoris muscle and the iliotibial band

Parapatellar Incisions

As recorded previously the parapatellar incisions so commonly employed at the pres-

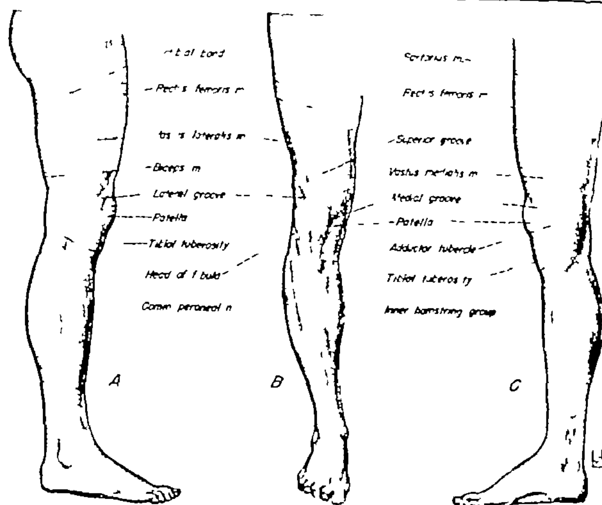


Fig 388 Landmarks on the anterior anteromedial and the anterolateral aspects of the knee joint.

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On the anterior aspect of the knee joint the patella stands out as a prominent bony mass the configuration being detected readily by inspection and palpation With the knee extended and the quadriceps relaxed this bony mass can be displaced with ease upward downward and to either side Extending proximally from the base of the patella the tendon of the rectus femoris muscle is readily discernible the same is true of the patellar tendon which extends from the apex of the patella to the tibial tuberosity The length of the patellar ligament is approximately 5 cm its mid point *lies opposite the joint line In the presence* of a large effusion in the knee joint the mobility of the patella is increased greatly and ballottement of this bone can be demonstrated by tapping it gently this maneuver causes the patella to strike the anterior surface of the femur with each tap of the finger the contact can be both felt and heard

In the intervals between the lateral margins of the patella and the corresponding femoral condyles a distinct furrow is present running parallel with the patellar border In thin individuals the furrows are deep and well demarcated while in individuals with large quantities of subcutaneous fat

they may be shallow or obliterated Another depression is discernible above the base of the patella connecting the two lateral fur rows and producing a horseshoe shaped peri patellar furrow (Fig 388) The grooves parallel the upper and the lateral boundaries of the suprapatellar pouch. In knee joints distended with blood or an effusion, the peripatellar furrows are ballooned out to form semicircular convexity around the lat eral margins and the base of the patella As recorded previously, the patella is freely movable with the knee extended, by displacing the patella laterally or medially the corresponding borders of the condyles of the femur can be palpated.

When flexion of the knee joint is initiated the patella stands out as a prominent bony structure in the anterior aspect of the joint As flexion continues the patella becomes less prominent and more fixed in full flexion it lies deeply in the intercondylar notch of the femur, and then no lateral motion is demon strable the apex of the patella lies opposite the joint lines, and the articular surface of the intercondylar notch is palpable immedi ately proximal to its base

Below the apex of the patella and on either side of the patellar ligament the pyramidal infrapatellar fat pad produces a soft fullness which becomes more prominent and tense when the quadriceps muscle is contracted with the knee fully flexed the fullness on either side of the patellar liga ment is accentuated but remains soft On either side of the patellar ligament the joint between the femoral condyles and the tibia is readily palpable this is particularly true when the knee is in a flexed position In the region of the collateral ligaments the joint line is barely distinguishable because it lies under cover of these structures.

On the lateral aspect of the joint several pertinent structures must be considered The enlarged anterior portion of the lateral condyle of the femur lies slightly in front of and proximal to the head of the fibula this feature is demonstrated best when the knee is flexed. The biceps tendon is readily pal pable as it approaches its site of insertion into the head of the fibula The common peroneal nerve descends along the lateral side of the popliteal fossa in relation to the inner border of the biceps femoris muscle At the level of the superior border of the head of the fibula it becomes superficial and then proceeds to wind around the neck of the fibula lying between the peroneus longus muscle and the bone In thin indi viduals the nerve can be palpated as it winds around the neck of the fibula.

On the medial aspect of the knee joint the most prominent structure is the medial femoral condyle, which is readily palpable The upper and inner boundary of this con dyle ends in the adductor tubercle into which inserts the tendon of the adductus magnus muscle This tubercle lies on a line with the distal epiphyseal plate of the femur It is slightly proximal to the upper limits of the articular surface of the trochlea of the femur In their course downward the sartorius and the gracilis muscles wind around the posteromedial aspect of the con dyle and then proceed forward to reach the medial aspect of the upper end of the tibia they are in relation to the semitendinosus and the semimembranosus (Fig 395)

On the anterior aspect of the knee joint, with the leg extended actively the tendon of the rectus femoris muscle stands out promi nently and its lateral borders are readily detectable The bulge of the vasti muscle on either side of the tendon of the rectus fem oris is plainly visible The prominence of the vastus lateralis is at a much higher level and is less pronounced than that of the vastus medialis (Fig 388) In active exten sion of the leg a deep groove is present distal to the prominence of the vastus lateralis between the tendon of the rectus femoris muscle and the iliotibial band

Parapatellar Incisions

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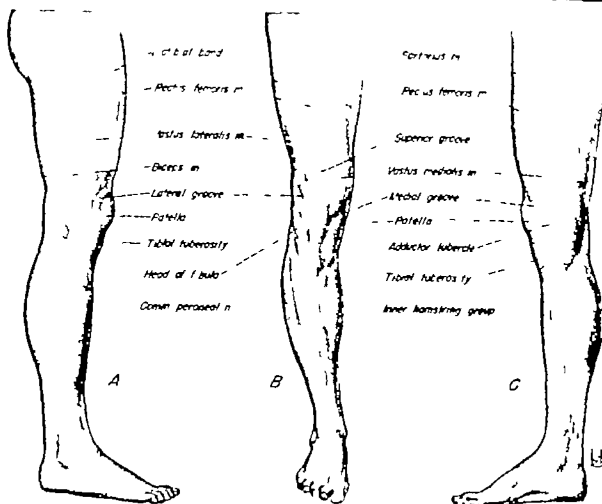


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Parapatellar Incisions

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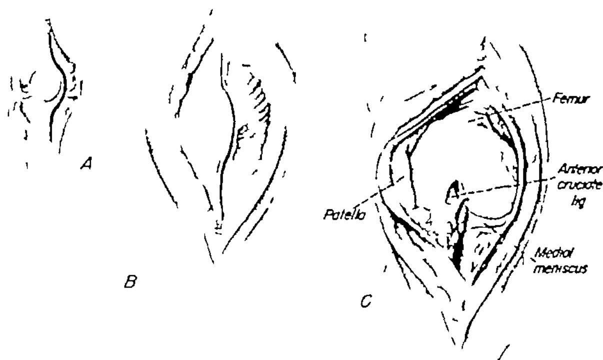


FIG 389 (A and B) Median parapatellar incision (von Langenbeck) (Krida) (C) Observe the extensive exposure of the interior of the knee joint.

ent time were devised in the late decades of the nineteenth century In 1878 von Langenbeck devised a median parapatellar approach *leaving the patellar ligament intact* and Kocher (1894) designed a similar lateral parapatellar incision These incisions were popularized by Krida (1925) and have come to be known as general utility incisions " a designation first used by Krida Parapatellar incisions have gained much favor among orthopedic surgeons of all parts and are indicated when wide exposure of the joint is desired

Median Parapatellar Incision. The median parapatellar incision is particularly useful in cases requiring surgical exploration also it facilitates the execution of the following surgical procedures synovectomy removal of foreign bodies excision of the infrapatellar fat pad reconstruction or repair of the cruciate ligament removal of osteochondral fragments resulting from osteochondritis and removal of deteriorated cartilage from the articulating surface of the patella in cases of chondromalacia

The patient is placed in the supine position, and the extremity, after it is enclosed in sterile stockinette rolled on separately *from the toes to the groin* is bent at the knee over a sandbag wrapped in a sterile covering or over a folded sterile sheet so that it is flexed from 20° to 30 The pertinent landmarks are the quadriceps tendon and the adjacent bulge of the vastus medialis the adductor tubercle the patella the patellar ligament and the tubercle of the tibia (Fig 388)

Von Langenbeck s Incision (Krida) (Fig 389) Beginning at the medial border of the quadriceps tendon from 3½ to 4 inches proximal to the upper border of the base of the patella the skin incision is carried distally following the medial border of the quadriceps tendon the medial margin of the patella and the patellar ligament to a point just distal to the lower border of the tubercle of the tibia After the skin is retracted to either side the deep fascia is incised and the quadriceps tendon is exposed Next a vertical incision is made in the

quadriceps tendon 1 cm. lateral to its medial border, it is carried distally, curving around the medial margin of the patella and the patellar ligament In its path the incision divides the medial aponeurosis of vastus medialis. Division of the quadriceps tendon and deep aponeurosis of the vastus medialis permit visualization of the medial border of the suprapatellar pouch as it projects under the quadriceps tendon The synovialis is divided 1 cm. from the medial border of the patella and the patellar ligament. Finally the patella is dislocated laterally so that it lies to the outer side of the external condyle, and its articular surface faces anteriorly In some cases it may be necessary to mobilize the patella to a greater extent in order to facilitate its lateral displacement. This can be achieved by dividing the periosteum below the tubercle of the tibia and reflecting it outward enough to free the inner portion of the insertion of the patellar tendon

This approach gives an excellent exposure of the inside of the articular cavity of the knee joint, the view can be improved by flexing the knee to a right angle while the patella is held on the lateral aspect of the external condyle of the femur The structures visualized are both condyles of the femur portions of the cruciate ligaments, both menisci the infrapatellar fat pad, the ligamentum mucosum and the lateral extensions of the infrapatellar fat pad the articular surface of the patella and the posterior surface of the patellar ligament, the anterior borders of the upper end of the tibia and the suprapatellar pouch. Closure of the incision is facilitated by removing the support under the knee and placing it under the heel by so doing the position of the knee joint is changed from one of flexion to one of extension It is not necessary to close the wound in layers Closure is achieved readily by interrupted sutures, including the synovialis the deep aponeurosis and the fascial layers the subcutaneous layer and the skin are closed separately The author uses No 40 cotton as suture material for all closures



Fig 390 (*Left*) Incision of Payr (*Right*) Incision of Erkes

Fisher's Modification of von Langenbeck's Incision The incision designed by Fisher is a modification of von Langenbeck's approach, the skin incision is essentially the same except that the skin is reflected laterally as far as the lateral border of the patella. This is executed readily by sharp dissection Next a vertical mid line incision is made through the three fascial layers covering the quadriceps tendon, the patella and the patellar ligament On the inner aspect of the patella the deep fascia and the superficial aponeurotic layer blend to form a single structure making it possible to reflect these layers medially as a single sheet The deep aponeurotic layer and the synovialis beneath it are incised medial to the patella this incision is carried upward through the fibers of the quadriceps tendon lateral to the insertion of the vastus medialis In order to mobilize the patella the patellar ligament is dissected free along its medial margin as far as the tibial tubercle This permits lateral dislocation of the pa

tella exposing the inside of the articular cavity As pointed out by Abbott and Carpenter greater access to the joint may be attained by one of the following ways (1) by extending the incision on the quadriceps tendon to a higher level (2) by projecting the upper end of the incision obliquely inward and separating the fibers of the vastus medialis (3) by dividing longitudinally the inner border of the alar ligament and the adjacent fat pad and (4) by *mobilizing the inner border of the insertion* of the patellar ligament by subperiosteal dissection

Payr s Modification (Fig 390) Payr described *an S-shaped median parapatellar incision* which begins about 3½ to 4 inches proximal to the base of the patella in the mid line it continues vertically downward to just proximal to the patella then curves around its medial border and is continued downward along the medial border of the patellar ligament (Fig 390) Next an incision is made through the conjuncture of the fibrous insertion of the vastus medialis and the quadriceps tendon this limb of the incision is continued distally along the medial border of the patella and the patellar ligament cutting through the aponeurosis of the vastus medialis as it proceeds downward to the level of the tubercle of the tibia The synovialis which now comes into view is divided exposing the inside of the joint cavity Lateral dislocation of the patella to the outer side of the external condyle completes the final step in the exposure

Erke s Incision (Fig 390) This incision is rarely used because the median parapatellar incisions described are executed more readily and give greater exposure of the inside of the joint Essentially it is an oblique incision beginning over the medial epicondyle of the femur and is carried downward and inward as far as the insertion *of the patellar tendon into the tubercle* of the tibia The next step is division of the fibers of origin of the vastus medialis from the internal intermuscular septum This allows displacement of the patella and exposure of the underlying synovialis The synovial membrane is divided to secure access to the joint cavity

Lateral Parapatella Incision (Kocher) (Fig 391) This is the most widely employed lateral parapatellar incision Primarily it is used to expose the anterolateral aspect of the knee joint, also, it is a valuable approach for the surgical treatment of certain condylar fractures of the femur and *to remove loose bodies from the joint* The landmarks are the lateral femoral condyles the head of the fibula the vastus lateralis the quadriceps tendon the patella the pa*tellar tendon and the tubercle of the tibia*

The skin incision begins on the lateral aspect of the knee joint approximately 3½ to 4 inches above the base of the patella *It is continued downward and slightly in*ward crossing the parapatellar region of the joint At the level of the joint line it begins to curve forward crossing the tibial tubercle A vertical incision is made in the aponeurosis of the vastus lateralis 1 cm from the lateral border of the patella the incision is extended upward through the quadriceps tendon medial to its lateral border and downward through the aponeurosis of the vastus lateralis to the insertion of the patellar tendon into the tibial tubercle Then the synovial membrane is incised exposing the inside of the joint cavity In some instances in order to dislocate the patella medially it may be necessary to elevate the insertion of the patellar tendon by subperiosteal dissection or to detach it from the tubercle together with a piece of cortical bone The disadvantage of this incision lies in the complete detachment of the patellar ligament this delays restoration of function of the knee joint or as noted by Putti when the tendon is detached with a piece of bone nonunion may ensue If the insertion *of the patellar tendon* is detached either subperiosteally or subcortically caution must be taken not to divide the periosteum at the distal end of the tibial tubercle since

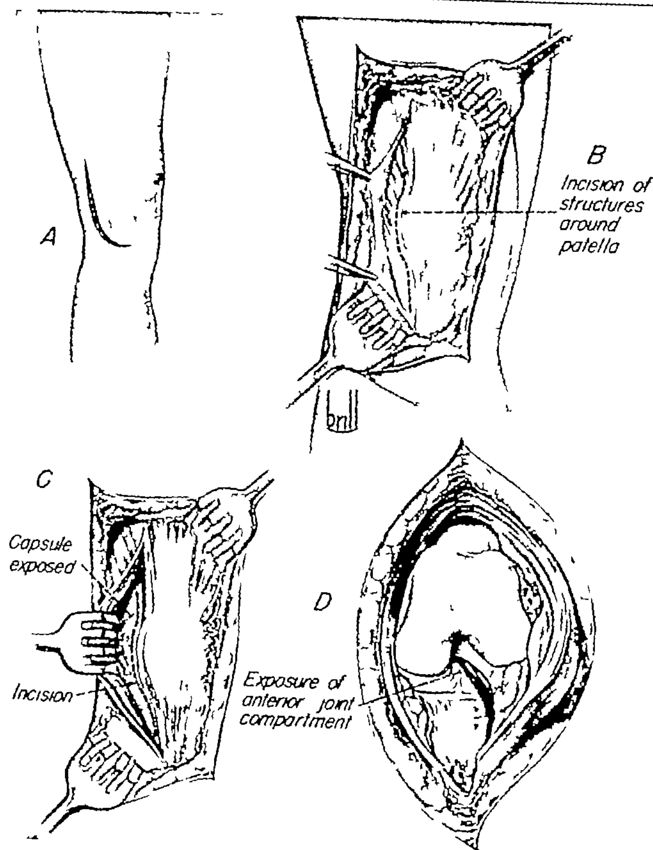


Fig 391 Lateral parapatellar incision (Kocher)

it is the only structure remaining which anchors the tubercle to the tibia after the operation

A similar median J-shaped incision provides better exposure of the joint cavity and inflicts less damage to the tissues Lateral displacement of the patella can be achieved readily without detachment of the tibial in

sertion of the patellar tendon Of the two J shaped approaches the medial one is preferred for exploration of the joint

Anteromedial and Anterolateral Approaches

Many anteromedial and anterolateral incisions were designed primarily to remove torn or lacerated menisci from the knee joint A great many of them allowed visualization of only that portion of the meniscus lying anterior to the lateral collateral ligaments For a time the necessity for removal of the entire meni cus was not universally understood and these incisions gained much popularity However they lost favor rapidly when it became apparent that complete removal of the meniscus was desirable With this change in the trend of surgery of the menisci new incisions were devised, such as the incisions of Fisher Cave and Bosworth This latter group of incisions also facilitated mobilization and removal of cysts of the menisci and removal of torn posterior segments of menisci which were left behind at previous operations performed through limited anterior approaches

Certain of the smaller anteromedial and anterolateral incisions are still employed by experienced and skillful surgeons who can remove the menisci in toto through such small approaches but they are not recommended for general use A great variety of these incisions have been described over the years In general all of them are placed in the interval between the lateral margins of the patella and the patellar tendon and the corresponding lateral collateral ligament They gain access to the joint cavity by dividing the aponeurosis of the vasti and the synovial membrane in this region Their direction varies it may be transverse oblique or vertical others are a combination of the aforementioned incisions following a curved direction The small transverse incision first described and employed by Annandale of Edinburgh (1879) provides limited exposure of the meniscus and except in the hands of skillful surgeons, makes excision of the entire meniscus very difficult despite the claims of some surgeons For this reason it is seldom used Smillie objects to this incision because it divides the skin the synovial membrane, the capsule and the aponeurosis at right angles to the direction of their fibers he believes that a broad weak scar results in these structures However, the author never has seen such unfavorable sequelae following transverse incision in this region.

Surgical Anatomy Anteromedial and anterolateral incisions are confined to the triangular interval between the apex of the patella and the patellar tendon in front the respective condyles and the anterior margins of the collateral ligaments behind and the upper border of the tibia below The significant landmarks are the same for incisions on the medial and the lateral aspects of the joint they are the patella the patellar tendon the tibial tubercle the femoral condyles and the anteromedial or anterolateral joint line In addition on the medial side one finds the adductor tubercle and the infrapatellar branch of the saphenous nerve The structures exposed by these incisions are the infrapatellar fat pad and its lateral projection the ligamentum mucosum the portion of the menisci anterior to the collateral ligaments the origin and a portion of the anterior cruciate ligament portions of the articular cartilage of the femoral condyles and of the tibial plateaus.

In all the aforementioned approaches the extent of the exposure of the anterior region of the joint is approximately the same The essential difference in all of them is the direction of the incisions in the skin the aponeurosis and the synovial membrane Of this group the curved incisions provide best access to the joint Fisher s curve sion has its convexity placed while that of Sir Thomas Jo terior convexity the infr of the saphenous nerve divided in the latter thr

sion. This complication is not considered to be of any real significance in the minds of some surgeons, however, if possible, it is desirable to avoid division of the nerve All these incisions may be used on either side of the joint, depending upon whether the surgeon desires to attain exposure of the medial or the lateral regions of the articular cavity

Anteromedial Curved Incision (Fisher) This incision (Fig 392) is used for excision of the internal meniscus a similar lateral incision is used for removal of the external structure

With the patient in a supine position and the knee flexed 90° over the end of the table a curved skin incision with its convexity posteriorly is made. The upper vertical limb of the incision parallels the anterior edge of the tibial collateral ligament, and the lower horizontal limb curves forward as far as the medial margin of the patellar ligament slightly below the joint line. The aponeurosis of the vastus medialis and the underlying synovial membrane are divided in the same line of the skin incision The inside of the articular cavity is now accessible the incision allows the tibial collateral ligament to be retracted readily thus permitting visualization of the anterior and the lateral attachments of the meniscus. The author employs a slight modification of this incision (Fig 393) Complete removal of the meniscus is achieved readily if the technic

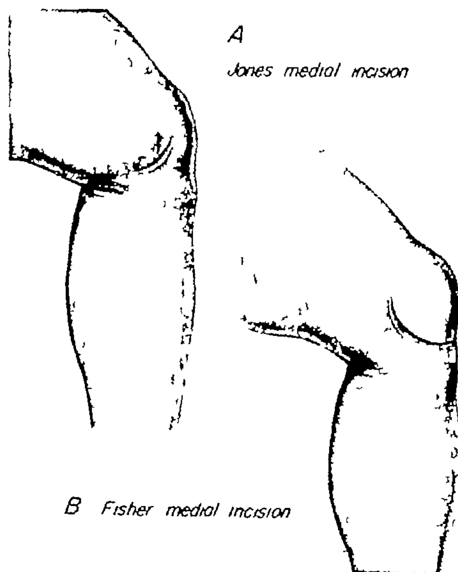


Fig 392 Anteromedial incisions of (A) Jones and (B) Fisher

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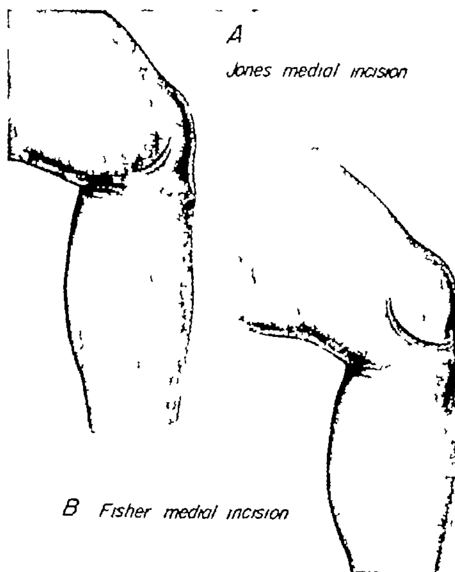


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Anteromedial Curved Incision (*Fisher*) This incision (*Fig 392*) is used for excision of the internal meniscus a similar lateral incision is used for removal of the external structure

With the patient in a supine position and the knee flexed 90° over the end of the table a curved skin incision with its convexity posteriorly is made The upper vertical limb of the incision parallels the anterior edge of the tibial collateral ligament, and the lower horizontal limb curves forward as far as the medial margin of the patellar ligament slightly below the joint line The aponeurosis of the vastus medialis and the underlying synovial membrane are divided in the same line of the skin incision The inside of the articular cavity is now accessible the incision allows the tibial collateral ligament to be retracted readily, thus permitting visualization of the anterior and the lateral attachments of the meniscus The author employs a slight modification of this incision (Fig 393) Complete removal of the meniscus is achieved readily if the technic

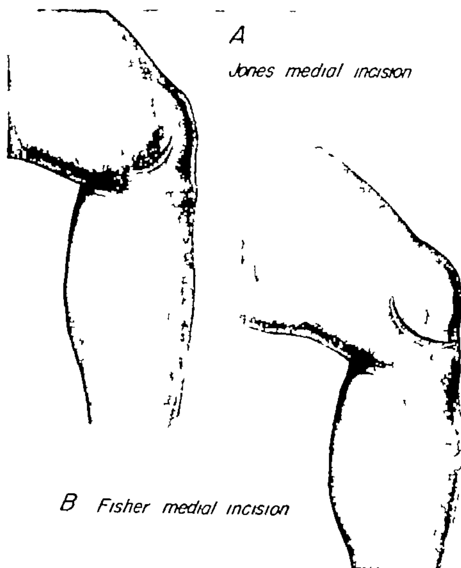


FIG 392 Anteromedial Incisions of (A) Jones and (B) Fisher

described in Chapter 5 "Affections of the Menisci" is executed meticulously On rare occasions more exposure is necessary to remove the posterior segment of the meniscus In such cases the skin incision depicted in Figure 393 is extended backward to a point 1 cm behind the medial epicondyle of the femur A second incision is made in the capsule behind the internal ligament It begins immediately below the epicondyle and continues slightly obliquely downward and forward This allows ample exposure of the posterior compartment of the joint and particularly the posterior segment of the fibrocartilage It also provides access to loose bodies in this region of the joint

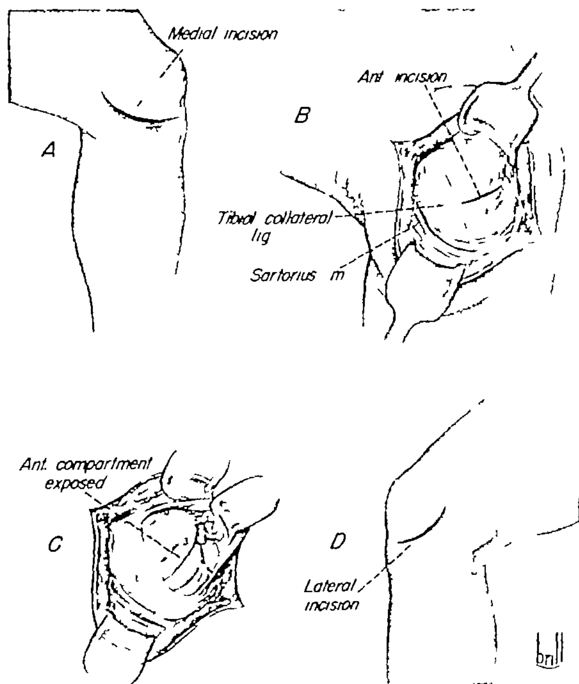


Fig 393 Modification of the Fisher incision employed by the author Extension of this incision posteriorly permits access to the posterior compartment of the joint

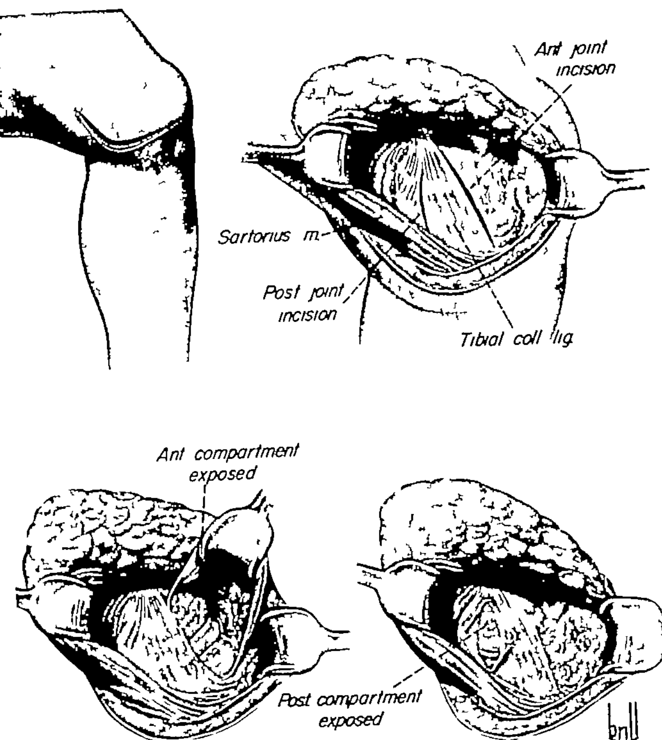


FIG 394 (A) Cave s incision utilized to gain access to the anterior and the posterior compartments of the medial side of the knee joint

Anteromedial Incisions Providing Access to Both Anterior and Posterior Compartments. The following incisions are particularly useful when a lesion of the posterior segment is suspected or when removal of a cyst of the meniscus together with the meniscus is desired They ensure excellent exposure of all the attachments of the meniscus facilitating their division under direct vision Similar incisions may be employed on the lateral side of the knee joint

The landmarks are the patella the patellar tendon, the tibial tubercle the femoral condyles and the anteromedial and antero-

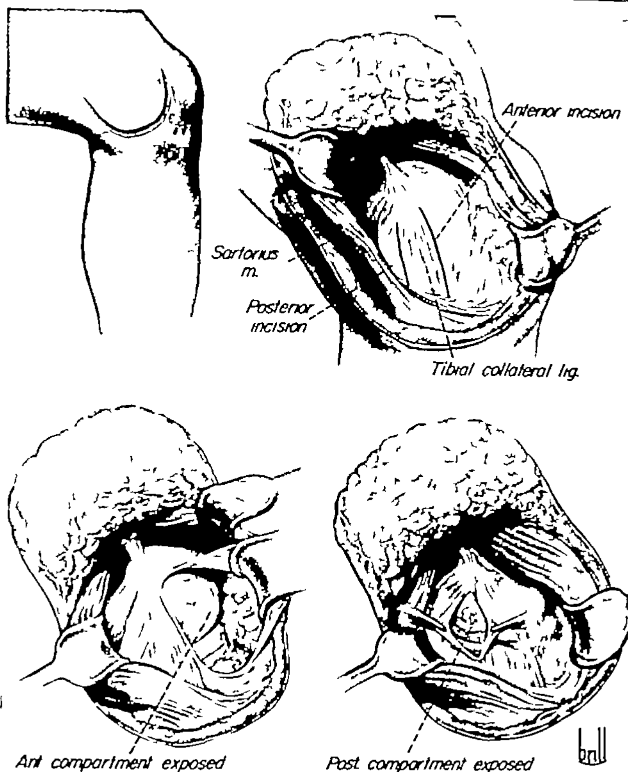


Fig 394 (B) Anteromedial curved incision (Fisher) employed to gain access to both the anterior and the posterior compartments of the joint

lateral joint line On the medial side one must note also the location of the infra patellar branch of the saphenous nerve and the site of the adductor tubercle while on the lateral side of the head of the fibula is a prominent landmark and the popliteus tendon in relation to the external meniscus and the fibular collateral ligament must be borne in mind

Anteromedial Curved Incision (Cave)

i the patient in a supine position and knee flexed 90° over the end of the ;, the skin incision begins approximately .. proximal and posterior to the epicon of the internal femoral condyle (Fig \) Its upper vertical limb curves down . to a point ½ cm below the joint line It continues forward as the horizontal to the medial margin of the patellar on The proximal flap of skin and sub- ieous *tissue is freed by sharp dissection* . aponeurosis of the vastus medialis and :cted upward thus exposing the tibial teral ligament Anterior to the tibial .teral ligament an oblique incision is e through the aponeurotic expansion of /astus paralleling its fibers The capsule the synovial membrane are incised in same *line. A similar incision is made* enor to the superficial portion of the l collateral ligament, thus opening the ule and the synovialis in this region parts of the internal meniscus and its chments are visualized clearly also the ipatellar fat pad, the origin of the an r cruciate ligament, the medial projec of the infrapatellar fat pad and the nentum mucosum are brought into view he approach described by Bosworth is lar to the incision of Cave except that skin incision over the anterior medial *ct of the joint follows an oblique direc* extending upward and slightly back d. The vertical incision anterior to the il collateral ligament is made with the e extended, while the vertical incision :erior to the same ligament is made with knee flexed.

.nteromedial Curved Incision to Fa tate Removal of Posterior Horn sher) (Fig 394 B) The following de ption refers to excision of the internal iiscus a similar incision can be em 'ed for the removal of the external me- ns The patient is placed in the supine ition with the knee flexed 90° over the of the table This approach is divided) two stages. In the first stage the anterior limb of the incision is made, at its completion, the pathologic nature of the meniscus is ascertained If its removal is deemed possible, the second stage of the operation is not performed On the other hand, if it becomes apparent that removal of the posterior portion of the meniscus is not possible or is going to be exceedingly difficult, then the second stage of the opera tion is executed In the first stage the skin *incision begins at a point midway between* the patellar ligament and the anterior mar gin of the tibial collateral ligament on a line with the apex of the patella It curves downward and backward as far as the an terior margin of the tibial collateral liga ment slightly below the upper border of the tibia The infrapatellar branch of the saphe *nous nerve is identified and retracted* pos teriorly The joint cavity is exposed by an incision through the aponeurosis of the vastus medialis and the synovialis in the same line as the skin incision it is pre ferred to extend this incision a little nearer to the margin of the tibial collateral liga ment than the skin incision Then the sec ond stage of the operation, if deemed neces- sary is performed The incision previously made is closed temporarily with a moist, warm pack of gauze then its distal limb is continued across the inner side of the joint *just below the joint line and projected up* ward and backward over the inner aspect of the posterior compartment of the knee joint, thus producing a semicircular flap of skin and subcutaneous tissue By reflecting the flap upward the tibial collateral liga ment comes into view A curved incision is made in the capsule and the synovialis im mediately posterior to the collateral liga ment This provides an excellent exposure of the posterior region of the medial side of the knee joint and of the posterior portion of the meniscus with its attachment.

Fisher advocated this incision not only for removal of the menisci but also for re- moval of loose bodies in the anterior and the posterior compartments of the joint By

extending the anterior limb of the incision upward the suprapatellar pouch is made accessible should exploration of this region be desired

Surgical Approaches to the Medial Region of the Knee Joint

Surgical Anatomy (Figs 395 and 396) Knowledge of the pertinent structures of the medial aspect of the knee will facilitate surgical approach to this region. The structures of particular significance are the tibial collateral ligament the internal intermuscular septum the tendons of the sartorius the gracilis and the semitendinosus muscles the bursae in relation to these muscles and the tibial collateral ligament the saphenous branch of the highest genicular artery (arteria genu suprema), the saphenous vein the saphenous nerve and the branches of the medial femoral cutaneous nerve

The tibial collateral ligament is by far the most important structure on the medial aspect of the knee joint A detailed description of this ligament has been recorded previously Separating the anterior compartment of the knee joint from the popliteal space is the internal intermuscular septum This structure is a fascial projection from the fascia lata which proceeds inward, inserting into the linea aspera and fusing with the tendon of insertion of the adductor magnus muscle It forms a fascial partition between the vastus medialis in front and the adductor magnus and longus behind. On the posteromedial aspect of the joint are

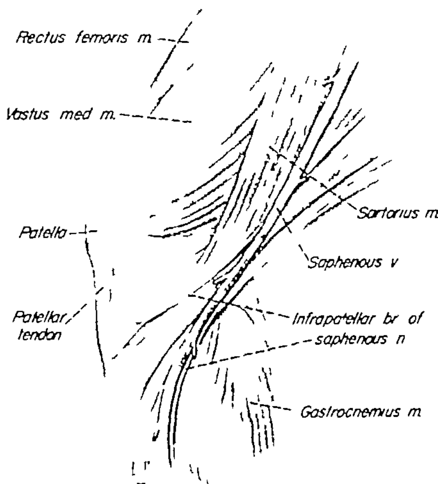


Fig. 395 Superficial structures on the medial aspect of the knee and their anatomic relation to one another

found the sartorius the gracilis and the semitendinosus muscles as they sweep around the medial femoral condyle and then continue forward and inward to reach the site of insertion on the anteromedial surface of the upper end of the tibia. Between these tendons and the tibia lies a large bursa. All three tendons cross the distal segment of the superficial layer of the tibial collateral ligament on the way to their insertion where they conform to a specific configuration, the tendon of the sartorius occupies a position anterior to the tendons of the gracilis and the semitendinosus Another bursa is present between the tendons and the terminal fibers of the tibial collateral ligament.

Both the anterior and the posterior branches of the medial cutaneous nerve of the thigh are encountered in this area. The anterior branch passes vertically downward and pierces the fascia lata at the junction of the middle and the lower thirds of the thigh, it continues distally for a short distance then proceeds lateralward to the anteromedial aspect of the knee where its terminal twigs enter into the formation of the patellar plexus The posterior branch descends along the posterior border, later occupying a position behind the sartorius and the saphenous nerve it continues downward to the middle of the calf The most important nerve in this region is the saphenous nerve a branch of the femoral nerve In Scarpa's triangle it lies lateral to the femoral artery At the apex of the triangle it enters and traverses Hunter's canal, in the canal it is

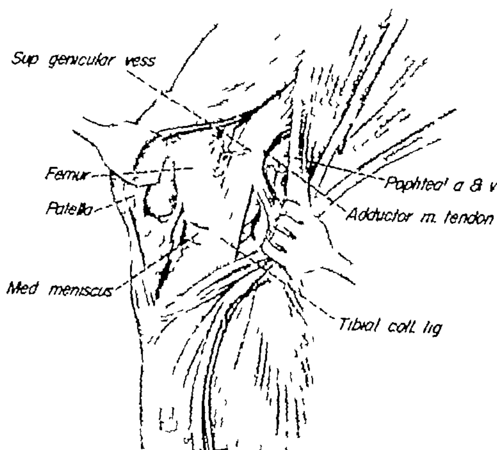


FIG 396 Deep structure on the medial aspect of the knee. Observe the arterial anastomosis in relation to the tibial collateral ligament and the position of the saphenous nerve

in relation to the femoral artery, lying first on its lateral side then in front of it and finally on the medial side of the artery Upon leaving the canal it is joined by a branch of the genu suprema artery, and together they descend between the posterior border of the sartorius and the anterior border of the gracilis Before it passes from under cover of the sartorius it gives off the infrapatellar branch that penetrates the sartorius just above the knee and lies on the anterior surface of the fascia lata. This branch continues distally and outward about 1 cm below the joint line its twigs are distributed to the anteromedial aspect of the knee joint that takes part in the formation of the patellar plexus

Deep to the tibial collateral ligament the superomedial and the inferomedial genicular arteries pass forward close to the femur and the tibia On the anterior aspect of the knee joint they join in the formation of the rich arterial anastomosis found here The internal saphenous vein in its course proximally crosses the posteromedial region of the joint It is in relation to the sartorius muscle. It lies first behind the tendon and then behind the muscle belly of the sartorius In relation to a bony landmark in this region it lies behind the epicondyle of the internal femoral condyle

Medial approaches are indicated primarily for surgery on the tibial collateral ligament Also they facilitate procedures demanding visualization of the anterior cruciate the internal meniscus and the medial hamstring tendons in addition to the tibial collateral ligament

The pertinent landmarks are the internal condyle of the femur and the adductor tubercle the inner condyle of the tibia the joint line the tubercle of the tibia and the medial hamstring muscles

S-Shaped Incision (Fig 397) The patient is placed in the supine position with the leg flexed 20 to 30° and slightly rotated externally This incision has an upper and a lower limb the upper limb is a long sweeping slightly curved incision with its convexity placed posteriorly on the posteromedial aspect of the knee joint. It begins about 5 cm proximal to the adductor tubercle directly over the tendons of the sartorius and the gracilis muscles It parallels the course of these muscles as far as the joint line then it curves forward to the anterior border of the upper end of the tibia The lower limb begins at this point It continues downward in a gentle curve with its convexity directed outward and terminates at the inferior border of the tubercle of the tibia The upper and the lower flaps which comprise skin and subcutaneous tissue are reflected upward and downward respectively from the deep fascia by sharp dissection A vertical incision is made in the deep fascia from the level of the adductor tubercle to the upper and the medial aspects of the tibia. Reflection of the flaps of the deep fascia brings into view the vastus medialis and its aponeurosis the tendinous insertion of the adductor magnus into the adductor tubercle the anterior superficial portion of the tibial collateral ligament the upper and the medial aspects of the tibia and the sartorius and the gracilis tendons Next the tendons of the sartorius the gracilis and the semitendinosus muscles are identified in the lower portion of the incision and displaced posteriorly This maneuver brings into view the oblique superficial posterior fibers of the tibial collateral ligament It will be noted that this portion of the tibial collateral ligament together with the fibrous capsule in this region winds around the posterior medial border of the internal condyle of the femur Other structures clearly seen are the insertion of the semimembranosus and the posterosuperior region of the upper end of the tibia Now the inner hamstring muscles the sartorius and the gracilis muscles together with the saphenous nerve and vein can be displaced posteriorly with ease permitting access to the popliteal space Immediately behind the tendon of the sartorius the saphenous nerve and its

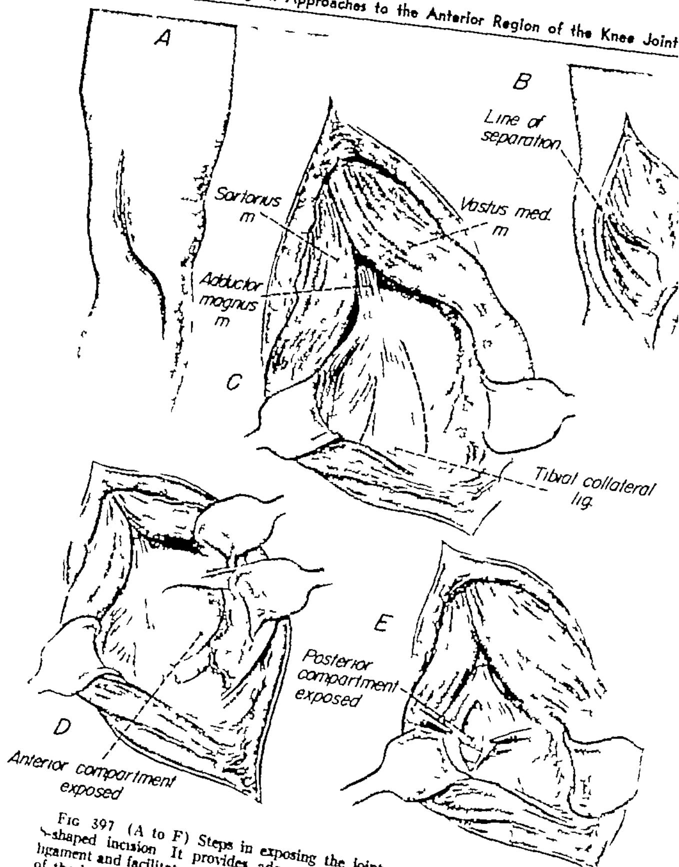


FIG 397 (A to F) Steps in exposing the joint cavity through a medial S-shaped incision It provides adequate exposure of the tibial collateral ligament and facilitates access to the anterior and the posterior compartments of the knee joint

infrapatellar branch and the posterior division of the medial femoral cutaneous nerve can be identified the infrapatellar branch of the saphenous can be traced along the inferior border and then through the tendon of the sartorius to its termination on the

anteromedial aspect of the knee joint about 1 cm. below the joint line

A vertical incision is made anterior to and parallel with the long superficial fibers of the tibial collateral ligament through the aponeurosis of the vastus medialis and the underlying synovial membrane By retracting the anterior and the posterior flaps of this last incision the entire anterior compartment of the knee joint is visualized the anterior cruciate ligament the anterior segment of the internal meniscus and the infrapatellar fat pad are seen clearly A similar incision through the oblique posterior fibers of the tibial collateral ligament and the synovialis exposes the posterior compartment of the joint. Now the posterior segment of the internal meniscus is clearly discernible

Through this approach the surgeon has access to the entire tibial collateral ligament the anterior, the middle and the posterior segments of the internal meniscus the infrapatellar fat pad and the ligamentum mucosum the anterior cruciate ligament all of the inner hamstring muscles and the sartorius and the gracilis muscles

Straight and Curved Incisions. Instead of the curvilinear S shaped incision described above a straight incision or a curved incision with its convexity directed posteriorly may be made on the medial aspect of the knee joint They extend from the adductor tubercle to the anteromedial aspect of the upper end of the tibia After the skin and the subcutaneous tissues are reflected from the deep fascia, the remaining steps of the approach are similar to those described for the S-shaped incision These incisions fail to provide the extensive

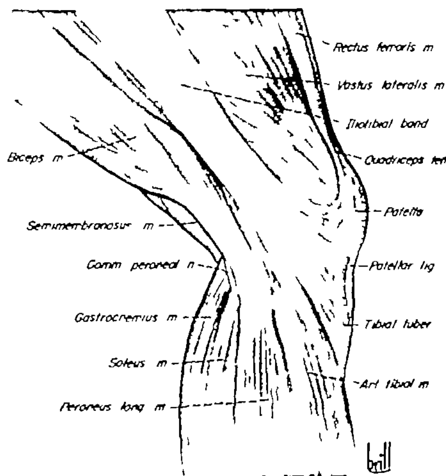


Fig 398 Superficial structures on the lateral aspect of the knee joint. Observe the anatomic relation of the common peroneal nerve

exposure of the medial region of the knee joint and of the joint cavity that is obtained with the S-shaped incision However they are valuable approaches when limited exposure is desired

Approaches to the Lateral Region of the Knee Joint

Surgical Anatomy (Figs 398 and 399) The structures of surgical significance on the lateral aspect of the knee joint are the iliotibial band the fibular collateral ligament the lateral intermuscular septum the head of the fibula, the common peroneal nerve the biceps tendon as it inserts into the outer aspect of the head of the fibula and the tendon of the popliteus muscle lying between the external meniscus and the fibular collateral ligament. The iliotibial band a tough tendinous band is the continuation of the tensor fascial femoris muscle which arises from the external lip of the iliac crest and the upper border of the notch between the anterior superior spine and the anterior inferior spine of the ilium and from the fibrous septum between it and the gluteus medius muscle The iliotibial band continues distally to insert into the upper border of the external tuberosity of the tibia it blends anteriorly with the aponeurosis of the vastus lateralis and posteriorly with the fibrous expansion of the biceps femoris

From the deep surface of the iliotibial band the lateral intermuscular septum passes inward to gain insertion into the linea aspera. This septum separates the vastus lateralis the biceps femoris and the anterior compartment of the knee and the popliteal fossa The tendon of the biceps winds around the superficial layer of the

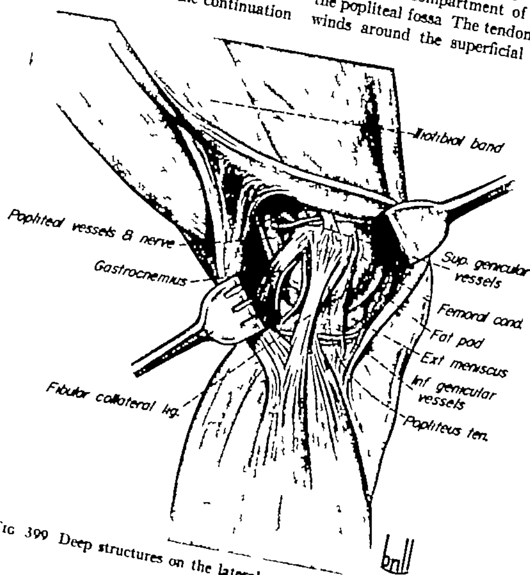


Fig 399 Deep structures on the lateral aspect of the knee joint

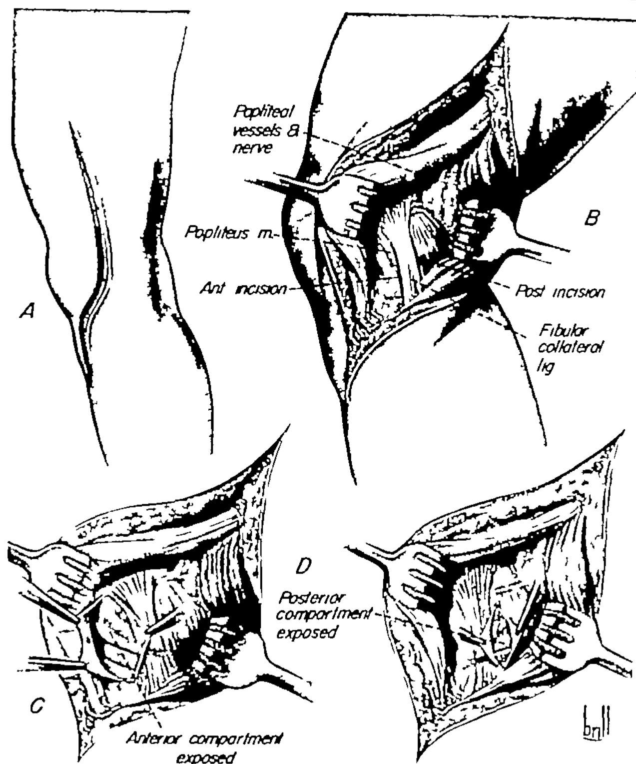


FIG 400 (A) Lateral S-shaped incision (B C and D) Observe the complete exposure of the fibular collateral ligament Both compartments of the knee joint are readily accessible.

fibular collateral ligament and inserts into the outer aspect of the head of the fibula Frequently between the tendon and the ligament a bursa is interposed

The fibular collateral ligament stretches from the lateral epicondyle of the external femoral condyle to the head of the fibula As recorded previously it comprises a deep and a superficial layer Between its deep surface and the external meniscus lies the tendon of the popliteus muscle which i directed obliquely upward and inserts into

the lateral epicondyle of the femur A prolongation of the synovial lining of the joint investing the popliteal tendon ends in a cul-de-sac in this region The important vessels on the lateral aspect of the knee are the superior lateral genicular and the inferior lateral genicular arteries The former passes under the tendon of the biceps and proximal to the attachment of the fibular collateral ligament on the femur it passes through the lateral intermuscular septum and is distributed to the vastus lateralis, the latter proceeds forward beneath the fibular collateral ligament proximal to its attachment to the head of the fibula

Lateral approaches are employed chiefly to gain access to the fibular collateral ligament the external meniscus and the external condyle of the femur Through these approaches, cysts of the lateral meniscus are removed readily however less-expansive incisions than the S-shaped incision to be described subsequently suffice for removal of uncomplicated cysts of the lateral meniscus The pertinent landmarks are the external condyle of the femur the head of the fibula the tendon of the biceps muscle the patella, the patellar tendon the iliotibial band and the lateral joint line

S-Shaped Incision (Fig 400) The patient is in a supine position, the leg is flexed over sandbags 20 to 30° and slightly internally rotated This incision consists of an upper and a lower limb The upper limb begins 5 cm proximal to the lateral condyle of the femur in the posterior aspect of the sulcus between the iliotibial band and the tendon of the biceps femoris muscle It sweeps forward along the upper border of the lateral tuberosity of the tibia The lower limb begins at the upper anterior border of the lateral tibial tuberosity and curves gently downward to the tubercle of the tibia The upper and the lower flaps which comprise skin and subcutaneous tissue are reflected upward and downward respectively from the underlying structures by sharp dissection This permits visualization of the tendinous fibers of the iliotibial tract, behind which is the tendon of the biceps muscle the fibular collateral ligament and the posterolateral portion of the fibrous joint capsule Behind the biceps tendon, the peroneal nerve can be identified and traced along its course as it winds around the neck of the fibula The entire fibular collateral ligament comes into view, its upper femoral attachment is clearly demonstrable, as is also its relation to the biceps tendon and to the tendon of the popliteus muscle which is seen to occupy a position posterior and deep to the fibular collateral ligament Access to the anterolateral compartment of the joint can be attained by dividing the aponeurosis of the vastus lateralis and the synovial membrane in a line directed downward and forward. Retraction of the flaps reveals the anterior segment of the external meniscus and the lateral portion of the infrapatellar fat pad The approach provides excellent exposure of all of the aforementioned extra articular structures particularly the fibular collateral ligament the biceps tendon the common peroneal nerve and the iliotibial tract it also makes the intra articular structures in the posterolateral and the anterolateral compartments of the joint readily accessible especially the external meniscus.

Straight and Curved Incisions. The S-shaped incision may be replaced by a straight or a curved incision with its convexity directed posteriorly They extend from a point 5 cm above and posterior to the lateral condyle of the femur to the anterolateral aspect of the upper end of the tibia The following steps are similar to those described for the S-shaped incision These incisions are indicated when less exposure than that provided by the S-shaped incision is desired

Posteromedial and Posterolateral Incisions

Surgical Anatomy The bilateral incisions in general use have the same surgical landmarks In the lateral region of the knee joint the pertinent landmarks are the lateral

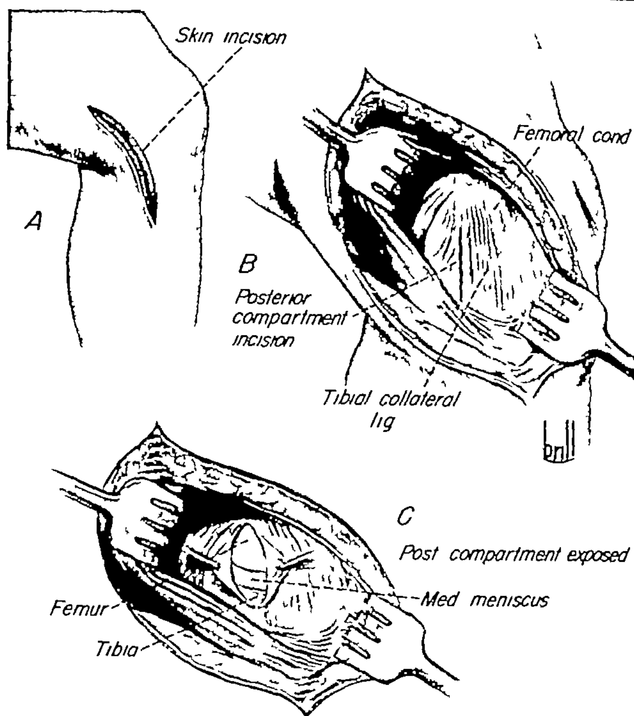


Fig 401 (A to C) Steps in exposing the posterior compartment through a posteromedial incision of the knee joint (Henderson)

condyle and the epicondyle of the femur the head of the fibula with the biceps tendon inserting into it the upper border of the lateral tuberosity of the tibia above which is the lateral one half of the joint line the fibular collateral ligament panning the interval between the lateral epicondyle of the femur and the head of the fibula the lateral intermuscular septum and the fibrous iliotibial tract The landmarks of surgical significance on the medial aspect of the joint are the adductor tubercle on the distal end of the femur the medial condyle of the femur the upper border of the medial tu

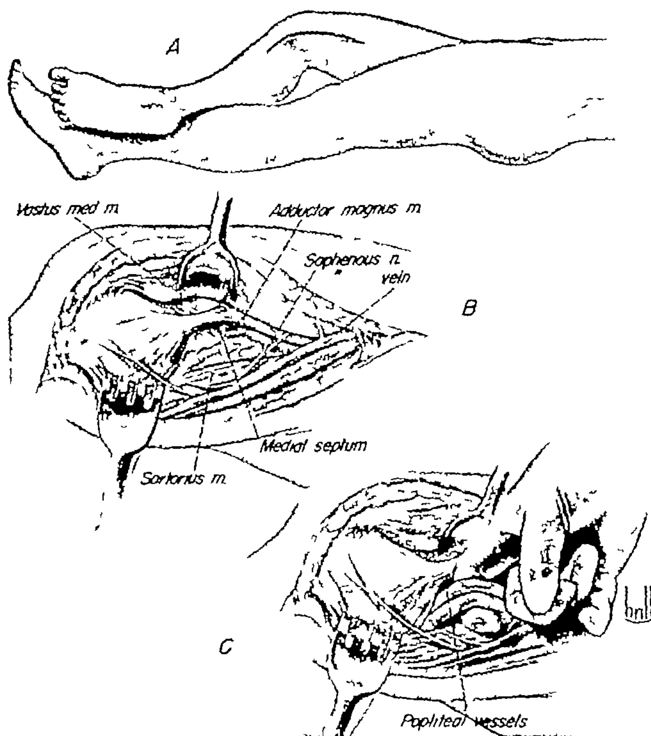


Fig 402 Medial approach for exposure of the popliteal face of the femur (Henry)

berosity of the tibia and the joint line proximal to it the tibial collateral ligament, the inner hamstring muscles and the sartorius and the gracilis muscles and the medial intermuscular septum On the medial aspect of the knee the medial intermuscular septum and the posterior border of the tibial collateral ligament form a partition separating the anterior region of the knee joint from the posterior region of the joint and the popliteal surface of the distal end of the femur Similarly on the lateral side, the lateral intermuscular septum and the fibular collateral ligament separate the anterior portion of the knee joint from the posterior compartment of the joint and the popliteal surface of the femur

Posteromedial and Posterolateral Ap-

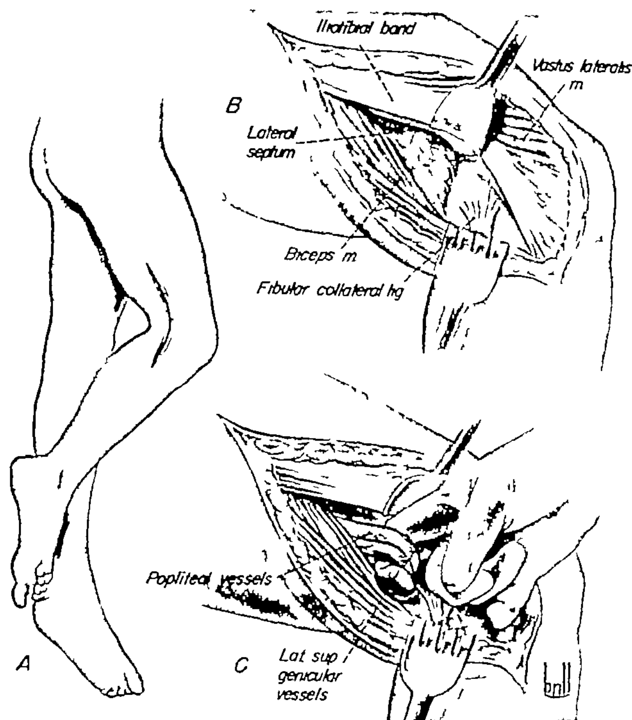


FIG 403 (A to C) Steps in the lateral approach for exposure of the popliteal face of the femur (Henry)

proaches (Henderson) These incisions facilitate removal of loose bodies from the posterior compartment of the knee joint The patient is placed in the supine position with the knee bent to a right angle over the end of the table

POSTEROMEDIAL APPROACH (Fig 401) The skin incision is from 3 to 3½ inches long it curves gently forward and downward beginning over the adductor tubercle and ending over the medial aspect of the tibia paralleling the fibers of the long superficial portion of the tibial collateral ligament Reflection of the skin and the subcutaneous tissue brings into view the tibial collateral ligament the aponeurosis of the vastu medialis and the lower portion of the sartoriu muscle Next the sartorius is displaced po-

teriorly, thus exposing the oblique posterior fibers of the tibial collateral ligament and the tendon of the semimembranosus muscle. A vertical incision is made in the oblique posterior portion of the tibial collateral ligament and capsule in the line of their fibers. Retraction of the capsular flaps permits access to the posteromedial compartment of the joint, the posterior portion of the medial femoral condyle and the posterior segment of the internal meniscus are visualized clearly

Posterolateral Approach A curved skin incision from 3 to 3½ inches in length, with its convexity directed anteriorly, is made in the sulcus formed by the biceps tendon posteriorly and the iliotibial tract anteriorly It extends in front of the fibular collateral ligament and ends on the lateral aspect of the tibia. The flaps comprising skin and subcutaneous tissue are reflected up and down exposing the iliotibial tract, and the tendon of the biceps femoris muscle In the upper end of the wound the external intermuscular septum is identified and followed to the linea aspera proximal to the lateral condyle of the femur The fibular collateral ligament is now demonstrable as it inserts into the epicondyle of the lateral femoral condyle Immediately below and posterior to the fibular collateral ligament the tendon of the popliteus muscle is seen running upward and forward to its insertion into the lateral aspect of the lateral femoral condyle By retracting the biceps tendon downward the posterior capsule of the joint is exposed Access to the posterior lateral compartment is achieved by incising the posterior capsule in its line of fibers retraction of the capsular flaps brings into view the posterior portion of the lateral femoral condyle and the posterior segment of the external meniscus.

Exposure of the Popliteal Face of the Femur (Henry) The patient lies recumbent with a sandbag under the buttocks of the unaffected side the foot of the affected extremity rests on the opposite shin as near the knee as possible. This position tilts the popliteal face of the femur upward (Fig 402)

Medial Approach (Fig 402) The skin incision follows the bend of the limb beginning 6 inches above the adductor tubercle and ending 2 inches below The lower flap of skin and subcutaneous tissue is freed from the underlying fascia for approximately 1 inch, exposing the sartorius to a point proximal to the adductor tubercle, the sartorius is mobilized by dividing the deep fascia in front of it, taking care not to injure the synovial membrane which lies immediately beneath the muscle Now the sartorius is retracted readily downward, thus exposing the tendon of the adductor magnus muscles and the saphenous nerve which lies deep to the sartorius. As the saphenous nerve leaves Hunter's canal it occupies a position in front of the adductor tendons In some instances the nerve is attached to the deep surface of the sartorius muscle, in others it lies free and unattached in the bend of the limb it is accompanied by the superficial branch of the genu suprema artery

Immediately posterior to the adductor tendon is found a loose thin fascia, which is opened readily to gain access to the popliteal face of the femur A finger is inserted into the opening with its dorsal surface against the tendon as far as the center of the popliteal face. Then the finger tip is flexed to locate the popliteal vessels which lie approximately 2 to 3 cm. from the bone Using the finger, the opening into the space is enlarged and the vessels are mobilized from the opening in the adductor magnus to the condyles of the femur The vessels together with the sartorius muscle are retracted backward in so doing some twigs of the popliteal vessels going to the bone come into view these are ligated and cut Now exposure of the popliteal face of the femur is complete and the region is readily accessible

Lateral Approach (Fig 403) The patient lies on the unaffected side with the

sound limb extended the knee of the affected extremity is placed just in front of the opposite knee so that the heel lies on the shin of the sound limb thus tilting the angle of the popliteal region upward An incision 6 inches long is made through the skin and the subcutaneous tissue it follows the bend of the flexed limb and lies about 3 to 4 cm in front of the biceps tendon paralleling the lower margin of the iliotibial tract It is carried down to the head of the fibula Next immediately proximal to the lateral condyle of the femur the deep fascia of the leg is divided just behind the lower margin of the iliotibial tract using this edge as a guide the incision is extended proximally taking care not to injure the synovial membrane in the region of the femoral condyle The biceps muscle and the external intermuscular septum are now clearly identified and the index finger is inserted in the plane between the two structures just proximal to the femoral condyle. The finger is passed along the popliteal face of the femur, freeing it from all attachments of the biceps muscle In so doing several branches of the perforating arteries will be encountered these are ligated and cut Dissection of the belly of the biceps muscle is continued to the upper limbs of the skin incision. Close to the condyle a finger is inserted into the wound with its dorsal surface against the lower edge of the iliotibial tract as far as the center of the popliteal face of the femur Then the finger is flexed, and the vascular bundle in the popliteal space is hooked the vessels are mobilized gently and retracted downward thus the entire popliteal face of the femur comes into view The large nerves of the thigh (tibial and common peroneal) are not exposed because they occupy a position behind the vessels in this region

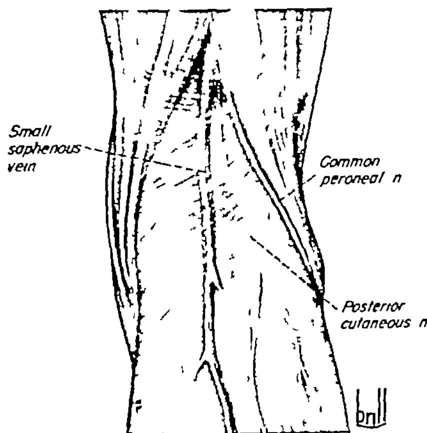


Fig 404 Superficial structures of the posterior aspect of the knee joint.

APPROACHES TO POSTERIOR REGION OF THE KNEE JOINT

Surgical Anatomy (Figs. 404 and 405) Comprehension of the anatomy of the posterior aspect of the knee joint is most essential because of the many important structures which are present in this region and because of the many indications which require access to it. As recorded previously the muscles crossing the posterior aspect of the knee joint form the boundaries of the popliteal fossa which is lozenge-shaped. Above its medial border is formed by the semitendinosus and the semimembranosus muscles below by the inner head of the gastrocnemius muscle On the lateral side the boundary is formed above by the biceps femoris muscle and below by the plantaris and the outer head of the gastrocnemius muscles The following structures from above downward comprise the floor of the fossa the popliteal face of the femur the oblique popliteal ligament, the upper end of the tibia and the fascial covering of the popliteus muscle. Posteriorly the roof of the fossa is formed by the popliteal fascia, which is an extension of the fascia lata. As pointed out by Abbott and Carpenter the

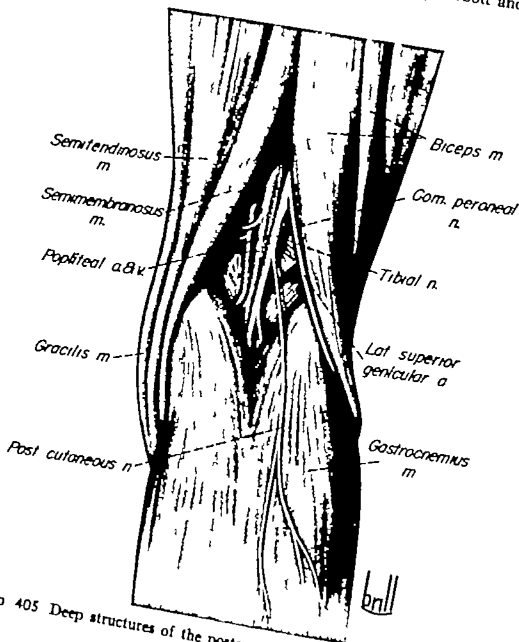


FIG 405 Deep structures of the posterior aspect of the knee joint.

popliteal fascia is fenestrated by certain structures which act as important surgical guides to other structures in this region The posterior cutaneous nerve of the calf is such a structure It occupies a position in the lower apex of the fossa between the two heads of the gastrocnemius muscle This *nerve is the uppermost branch of the tibial* nerve and arises in the popliteal fossa It descends between the two heads of the gastrocnemius muscle lateral to the external (short) saphenous vein approximately at the middle of the back of the leg it pierces the deep fascia and fuses with the anastomatic branch of the common peroneal nerve to form the sural nerve It becomes apparent that by identifying the posterior nerve of the calf and tracing it upward it acts as a useful guide to the tibial nerve and other structures within the popliteal fossa. The posterior cutaneous nerve of the thigh lies lateral to the posterior cutaneous nerve of the calf The aforementioned cutaneous nerves must not be mistaken for two other nerves in this region they are cutaneous branches of the common peroneal—the lateral cutaneous nerve of the calf and the anastomatic peroneal nerve Deep in the popliteal fossa and lying directly on its floor are the popliteal artery and vein From above downward the vein first lies on the lateral side of the artery then it crosses it and finally in the distal region of the fossa it lies medial to the artery In the fossa the genicular arteries leave the popliteal artery at right angles the tibial nerve lies beneath the popliteal fascia traversing the fossa from above downward through its center crossing the vessels posteriorly from a lateral to a medial position The common peroneal is found in the lateral aspect of the fossa under cover of the biceps muscle above and its tendon below

Mid line approaches to the posterior region of the knee joint are employed for removal of loose bodies in the posterior compartment of the joint for repair of the posterior cruciate ligament for release of flexion contractures of the joint for removal of tissues and cysts in this region and for exposure of the vessels and nerves in the popliteal fossa. The surgical landmarks are the boundaries of the popliteal fossa and the head of the fibula. The patient lies in a prone position with the affected limb slightly *flexed at the knee joint* and raised at a higher level than the opposite limb by a sandbag on a folded sheet

Mid line Incision (Fig 406) A curvilinear or S shaped skin incision is preferred to the vertical incision The curvilinear incision begins on the medial side of the lower end of the thigh from 8 to 10 cm proximal to the joint line It parallels the tendon of the semitendinosus to the joint line then curves laterally and downward crossing the posterior surface of the joint and continues distally over the outer head of the gastrocnemius The skin flaps are reflected by sharp dissection thus exposing the popliteal fascia In the lower end of the incision a vertical split is made in the deep fascia and the posterior cutaneous nerve of the thigh is identified It lies deeply between the two heads of the gastrocnemius muscle As noted previously the external saphenous vein runs parallel with this nerve along its lateral aspect *In the extreme lateral* aspect of the wound and under cover of the deep fascia are the anastomatic peroneal nerve and the lateral cutaneous nerve of the calf both are branches of the common peroneal They may arise singly or from a common trunk By tracing the posterior cutaneous nerve of the calf upward to its origin the tibial nerve is identified readily Once the tibial nerve is located it can be traced upward to the apex of the fossa where it joins the common peroneal to form the sciatic nerve and it can be followed downward to the distal portion of the fossa where it gives off muscular branches to the two heads of the gastrocnemius the soleus and the plantaris muscles The common peroneal can be followed downward until it winds *around the neck of the fibula* just

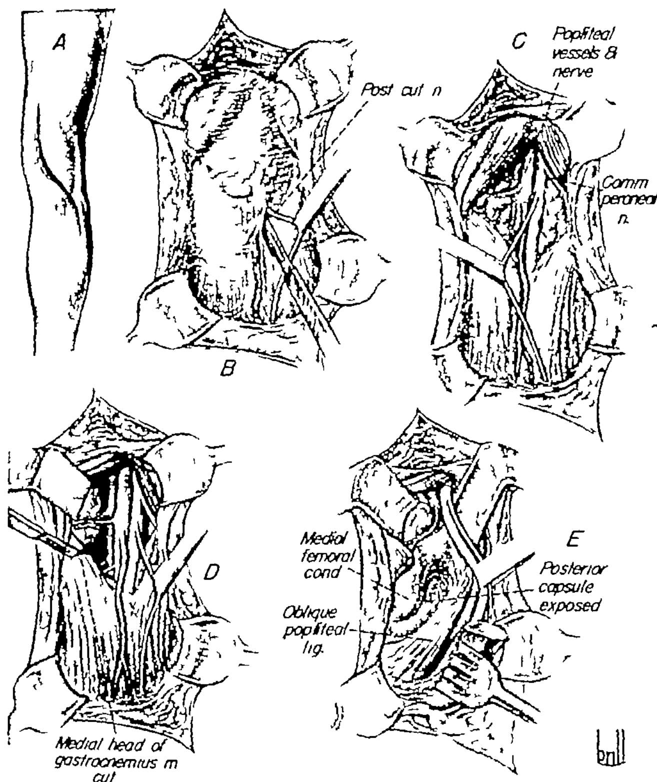


FIG 406 (A to E) Steps to gain access to the posterior aspect of the knee joint through a curvilinear incision

proximal to this point it lies between the outer head of the gastrocnemius muscle and the tendon of the biceps femoris On the floor of the fossa lie the popliteal artery and vein Exposure of these vessels reveals the origin of the genicular arteries Exposure of the medial aspect of the popliteal fossa may be increased by dividing and retracting laterally the tendon of the inner head of the gastrocnemius muscle A similar exposure may be obtained on the lateral side by sectioning the tendon of the outer head of

the gastrocnemius Further mobilization of the large vessels may be achieved by dividing some of the genicular arteries By retracting the vessels and the nerves the structures comprising the floor of the popliteal fossa is demonstrable Division of the posterior joint capsule and retraction of its flaps permits access to all the structures in the posterior compartment of the joint These structures are the posterior segments of the meni ci the posterior cruciate the posterior portions of the femoral condyles and the posterior aspects of the condyles of the tibia

Approaches Dividing the Patella

All the approaches to the knee joint which divide the patella provide excellent exposure of the entire joint except its posterior regions However these incisions disrupt the quadriceps apparatus in such a fashion that restoration of normal function is greatly retarded and in some instances impossible For these reasons they have been discarded and have been replaced by the parapatellar incisions The principal difference in the aforementioned incisions is the plane in which the patella is sectioned Devine s approach splits the patella in the sagittal plane von Volkmann divides the patella transversely Brackett and Hall and Jones split the patella in the vertical plane Bougot and De La Rue designed two incisions in one the patella is sectioned obliquely from front to back in another the patella is divided in the vertical plane

Approaches Dividing the Quadriceps Femoris Muscle or the Patellar Tendon

These approaches were designed primarily to facilitate arthroplasties of the knee joint However they are used occasionally for synovectomies and exploration of the joint As stated previously the last two procedures named are performed usually through parapatellar incisions The significant surgical landmarks are the quadriceps tendon the patella the patellar tendon the tibial tubercle and the condyles of the

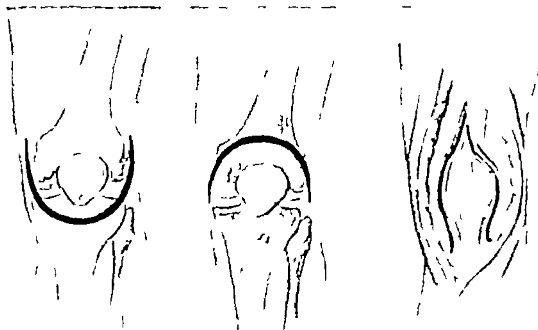


Fig 407 Incisions of (*left*) Textor (*center*) Putti (*right*) Coonse and Adams

femur and the tibia. The patient is in the supine position with the knee of the affected limb flexed from 20 to 30° over a sandbag

Incision Dividing the Patellar Tendon Transversely (Textor) (Fig 407 left) This incision is particularly useful in cases requiring excision of the joint The skin incision is U-shaped with its convexity facing downward it begins over the medial femoral condyle and curves downward and outward crossing the leg just distal to the insertion of the patellar tendon into the tubercle of the tibia It continues upward and outward ending over the lateral condyle of the femur Upward and downward reflection of the skin flaps uncovers the patellar tendon and its tibial insertion and the aponeurosis of the vasti muscles and the lateral aponeurosis of the vasti muscles Next patellar tendon and the synovialis are divided in the line of the skin incision taking care to preserve the integrity of the tibial collateral ligament on the inner side and the iotibial tract on the outer aspect of the int The proximal flap comprising the skin e aponeurotic expansions of the vasti and the patella is turned and retracted upward thus exposing the anterior region of the knee joint Flexion of the joint to a right angle increases the exposure bringing clearly into view the condylar portion of the femur the upper portion of the tibia the suprapatellar synovial pouch the menisci the articular surface of the patella the collateral and the cruciate ligaments the infrapatellar fat pad and the ligamentum mucosum

Some surgeons advocate this incision in severely septic joints in which case the joint may be held open by suturing the patellar tendon to the skin on the lower and anterior surface of the thigh

Incision Dividing the Quadriceps Muscles (Putti Campbell) (Fig 407 center) A curved skin incision U-shaped with its convexity directed proximally is made starting over the medial tibial condyle just anterior to the tibial collateral ligament it sweeps upward and outward across the anterior aspect of the joint from 2 above the base of the patella, the downward in front of and parallel to the fibular collateral ligament to terminate at the lateral tibial condyle The underlying structures comprising the fascia and aponeurosis of the vasti are cut in the line of the skin incision, while the tendon of the quadriceps is divided transversely just proximal to the base of the patella Some surgeons preferred to do a Z plastic incision in the quadriceps tendon rather than sectioning it transversely Retraction of the lower flap which contains the patella provides an excellent exposure of the entire knee joint except its posterior portion The exposure may be enhanced by flexing the knee to a right angle

Plastic Division of the Tendon of the Quadriceps (Coonse and Adams) (Fig 407 right) The first step in this approach is a curved medial parapatellar incision Reflection of the skin and the subcutaneous tissues reveals the quadriceps tendon, the patella the patellar tendon and the aponeurosis of the vastus medialis and the inner portion of the aponeurosis of the vastus lateralis Next, an inverted Y-shaped incision is made in the tendon of the quadriceps and the aponeurosis of the vasti and in the synovial membrane the upper limb of the inverted Y divides the quadriceps tendon vertically then it sweeps downward on either side of the patella, cutting through the aponeurosis of the vasti Complete access of the anterior compartment of the joint is achieved by reflecting the patella downward

SURGICAL PROCEDURES

Arthrodesis of the Knee Joint

Indications and Contraindications The goal of arthrodesis is twofold (1) to provide the patient with a stable painless limb in the position of optimum function and (2) to eradicate the existing patholog

processes responsible for the deformity or disability This is achieved by producing through surgical intervention, bony ankylosis of the affected joint Once an arthrodesis is decided upon and performed there is no turning back thus each case must be evaluated carefully particularly in regard to the advantages and the disadvantages of the procedure The indications for arthrodesis are (1) tuberculosis (2) flail joints, such as those resulting from anterior poliomyelitis, (3) neurotrophic diseases of joints particularly Charcot s joints (4) traumatic lesions producing gross incongruity of the articular surfaces usually following fractures with displacement of the tibial plateaus (5) advanced osteoarthritis traumatic or degenerative in origin causing severe pain and disability and (6) postinfectious arthritis leaving in its wake a disrupted joint with limited painful motion

Except in cases of tuberculosis arthrodesis should be the last measure employed to rehabilitate the patient This is especially true in traumatic and degenerative lesions. The value of other more conservative methods is first weighed and tried such as rest improvement of muscle tone and control particularly of the quadriceps group synovectomy débridement of the joint improvement of static alignment by osteotomy reconstruction of lax or torn ligaments and in cases of paralysis muscle transplants wherever possible. One is justified in performing an arthrodesis only after the aforementioned measures have failed to produce results acceptable to the patient or if in the judgment of the surgeon based on clinical experience they are not considered worthy of trial The handicaps of a fused knee are numerous it precludes a graceful smooth gait in a sitting position it may be a source of inconvenience and embarrassment and the patient is unable to kneel The enumerated disadvantages comprise a sacrifice that is made with great reluctance by the patient an unwillingness that is justifiable It becomes apparent that the advantages must outweigh the disadvantages of a fused knee joint before the surgeon is justified in recommending and performing this procedure

So far, only the unpleasantness of an arthrodesis has been emphasized However there is much to be said in favor of this operation. In tuberculosis regardless of the age of the patient arthrodesis has proved to be an effective means of inducing complete rest of the part a feature that is essential before the body forces can eradicate the disease In instances of gross instability of the knee joint arthrodesis allows the patient to discard cumbersome braces Cleveland recorded that 91 per cent of 80 patients with fused paralyzed knee joints were satisfied with the result of the procedure In patients with traumatic or degenerative arthritis causing pain and disability, arthrodesis provides a painless stable limb and restores the patient to a gainful occupation moreover the cure is permanent Except in tuberculosis the question as to the advisability of an arthroplasty instead of an arthrodesis arises frequently The specific indications of arthroplasty will be discussed subsequently however at this time mention must be made of the fact that even in the hands of the most experienced and skillful operators the results obtained by arthroplasty are not considered as satisfactory in a large percentage of the patients

Arthrodesis of Tuberculous Knee Joints

Evaluation of Arthrodesing Operations. Today it is common knowledge that arthrodesis of a tuberculous joint is a valuable adjunct in achieving complete rest until nature overpowers the disease and eradicates it The measure is not a cure and plays a secondary part to the more important role of the body as a whole No measure must be overlooked that will build up the natural resources of the patient and aid in localizing and eventually obliterating the pathologic processes Such measures include adequate rest pleasant and sanitary environment and

a diet rich in all the essential foods and vitamins The role of the antibiotics and chemotherapy looks promising the future may release some startling advances in these fields

Prior to the time of Rollier, extensive resection of the tuberculous knee joint was considered as the treatment of choice This radical procedure was followed invariably by unfavorable and sometimes tragic sequelae Extensive resections of the articular surfaces without adequate immobilization resulted in wide separation of the bone ends thus union was rarely achieved Secondary infections were encountered frequently In many instances the unfavorable complications associated with these secondary infections were responsible for the loss of the limb and in some instances the life of the patient Most of those who survived the ordeal demonstrated limbs distorted by contractures and they were of little or no functional value

These unfavorable results were responsible for the adaptation of more conservative measures The methods practiced and publicized by Rollier claimed more and more adherents. In fact, Rollier s slogan was ' Every case of tuberculosis can be healed if we have only the patience not to operate "

Critical analysis of the cases treated by the conservative methods advocated by Rollier disclosed that the immediate good result did not stand up under the test of time. Relapses of the pathologic processes occurred in a large number of cases which previously had been considered as cured Also in a large percentage of the healed cases the affected limb was of no functional value severe contractures and marked shortening of the extremities were the usual sequelae These factors forced surgeons to consider again a surgical approach to the problem. A combination of conservative treatment and surgical intervention gradually became popular The goal of the surgeons now was to achieve a bony ankylosis in the position of function without removal of large quantities of bone the surgery was performed at a time when the patient s general condition was considered to be good and the local lesion was controlled by the natural resistances of the patient The value of long periods of postoperative immobilization was recognized and practiced With such a regimen the number of healed patients with functioning limbs increased It is interesting to note that for many years prominent surgeons combined the arthrodesing procedures with excision of the synovial membrane

Age at Which Operation Is Advisable The age of the patient at which operation is deemed advisable is still a controversial topic For many years surgery was reserved for patients who had attained skeletal maturity, operation on children was discouraged and frowned upon Clinical experience has changed this view Now, age is no longer a consideration Between the ages of 3 and 5 osseous ankylosis is difficult to achieve because of the preponderance of cartilage tissue which comprises the ends of the epiphysis of the distal end of the femur and the upper end of the tibia. Nevertheless, even in these cases surgical intervention is preferred to conservative methods because they exhibit less residual shortening of the limbs and have fewer complications In performing arthrodesis of the knee joint in children, precaution is taken not to injure the epiphyseal plates, this may lead to growth disturbances in the form of angular deformities, shortening of the limb, or both In general, the degree of skeletal development governs the time of operation after the age of 8 the epiphyses of femoral and tibial condyles contain sufficient osseous tissue to assure bony alkylosis However, the writer's clinical experience substantiates the observations of McKeever and others that in young children intra-articular fusion may be achieved and that these children have better results than could be obtained with prolonged immobilization without surgical intervention

Haas report in 1940 is of great significance, and his observations have been sub-



Fig 408 (*Left*) Case J O, male, aged 9 Observe the complete bony ankylosis following surgical arthrodesis performed for tuberculosis of the joint at the age of 6 No evidence of any activity is evident clinically or roentgenographically The knee is in the ideal position (full extension) (*Right*) Two years after operation this patient sustained a slip of the distal femoral epiphysis following a fall minimal deformity was present which was reduced by manipulation. No disturbance of growth ensued

408) In the adult, from 10° to 20° of flexion at the knee is desirable It permits the patient to sit with ease The slight amount of shortening which results from an arthrodesis is advantageous to the patient because it facilitates walking the leg can be swung in walking without the foot s scraping the ground or without having to elevate the pelvis on the affected side or without having to swing the leg outward

Postoperative Management. Following most of the fusion operations except those utilizing compression the patient is placed in a single plaster spica extending from the iliac crest to the toes on the affected side. After 4 weeks most of the postoperative swelling will have subsided, the cast is removed the wound is inspected and a similar snug fitting spica is applied As a rule after 12 weeks clinical union is demonstrable although roentgenographic evidence of union may be slight or absent. The plaster spica is replaced by an unpadded skin tight plaster cylinder extending from the groin to above the malleoli, and weight bearing is permitted Later, the plaster cylinder may be replaced by a Thomas caliper knee brace, to which is added a leather corset that fits snugly around the limb It is worn day and night until there is roentgenographic evidence of an osseous ankylosis Even after bony fusion has been achieved, the limbs of adults should be protected by braces until continuous bony trabeculae crossing the site of operation are demonstrable by roentgenograms this may mean from 6 to 12 months or even more In children postoperative protection of the limb is even more important The long leg brace without a knee joint should be worn for several years in order to prevent slipping of the distal femoral epiphysis Some surgeons advocate its use until the age of 14 for some children.

ARTHRODESING PROCEDURES

Numerous operations have been designed to produce bony ankylosis in tuberculous knee joints Although extra articular arthro-

stantiated subsequently by many workers Although his series was small he pointed out that if the epiphyseal cartilage plates in growing children are not disturbed fusion is *obtained without loss of growth in the majority of the cases* and when shortening does occur it never exceeds ½ inch The youngest patient in this series was 2¾ years and the oldest 12½ years.

In the very young children the preponderance of cartilage and a small ossification center may preclude osseous contact In these cases removal of a thin layer of cartilage from the adjacent articular surfaces suffices a *bony ankylosis* may not occur but a fibrous union always will follow Later when the ossification center has increased in *size a second operation is done to obtain* osseous union

Optimum Time of Operation Another controversial point is the stage of the disease which may be considered as the optimum time to perform the arthrodesis. Many workers are of the opinion that the optimum time comes during the period of abatement of the disease or when the natural body resistance has controlled the activity and the *spread of the pathologic processes On the* other hand other noted authorities in the field have advocated operative interference as soon as the diagnosis is established

In the writer's clinic a middle course is chosen Arthrodesis is performed in the early stages of the disease before extensive disruption of the components of the joint has occurred and preferably when there is roentgenographic evidence that the lesion is controlled *and the osseous elements of the joint* are approaching normal Operation is not done in the face of an actively destructive process with acute clinical manifestations This would invite avoidable complications as increasing the intensity of the process and exposure of the patient to secondary infection or dissemination of the disease to other systems of the body Patients in this category are put at complete bed rest for 3 months *the affected extremity is encased* in plaster If a flexion deformity exists the limb is placed in balanced traction—forceful correction never is employed During this period supportive measures are added to *improve the physical status of the patient* small transfusions of whole blood are valuable adjuncts In addition 1 Gm. of streptomycin is *given daily to adults and ½ Gm* to children This is continued for the 90-day period The efficacy of this drug in tuberculosis of bones and joints has been established No doubt the future will give us an antibiotic or drug which will be even more effective than streptomycin After this period the patient is usually ready for arthrodesis of the knee joint.

Management of Existing Deformities. *Untreated or poorly managed cases of tu*berculosis of the knee joint may disclose varying degrees of axial deformity of the tibia on the femur and flexion contracture of the knee As a rule the limb is flexed at the knee abducted and rotated externally the tibia may be subluxated partially or completely on the femur Deformities of lesser degrees may be corrected at the time of operation by shaving the condyles of the *femur and the tibia to allow contact between* the surfaces with the knee in the position of election Severe deformity may require preliminary surgical procedures such as posterior capsulotomies tendon lengthening or osteotomies before arthrodesis can be considered After stability of the corrected position is assured which is between 4 and 6 weeks arthrodesis of the joint can be performed As noted previously at no time is *forceful correction of a deformity resulting* from tuberculosis justified

Position of Election of the Limb In children the position of election of the extremity following arthrodesis differs from that in adults In the children the knee is placed in full extension This precaution is essential because slight flexion tends to increase with weight-bearing and growth also slipping of the lower femoral epiphysis *is a common occurrence in children* (Fig



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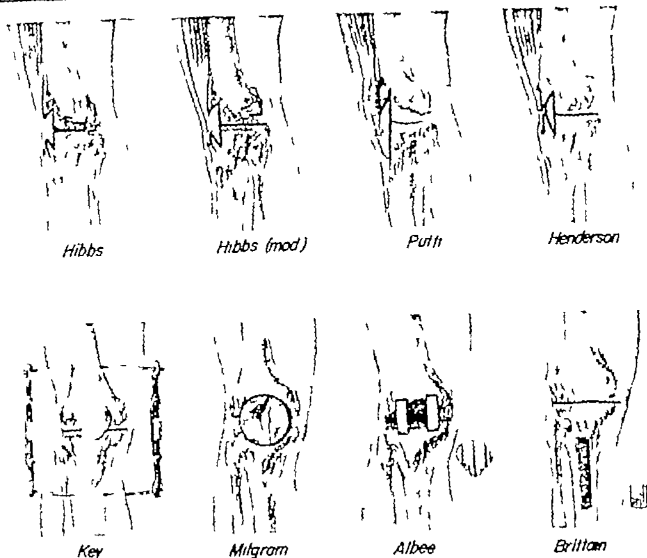


Fig 409 Some of the methods of arthrodesis of the knee joint.

medial side just below the adductor tubercle (Fig 409) It curves downward and outward to a point immediately below the insertion of the patellar tendon into the tibial tubercle and then continues upward ending at the lateral epicondyle of the femur In the line of the skin incision the aponeurosis of the vasti the patellar tendon and the joint capsule are divided preserving the tibial collateral ligament on the medial side and the iliotibial tract on the lateral side The entire flap which includes the patella and the patellar tendon, is reflected upward By flexing the knee all the structures in the anterior compartments of the knee joint are exposed The patella is excised and denuded of all tendinous tissue periosteum and cartilage In the original operation designed by Hibbs the patella was left attached to the quadriceps tendon in order to ensure adequate blood supply to the bone However the use of the patella as a free graft facilitates the procedure inasmuch as it is embedded in cancellous tissue of the femur and the tibia revascularization occurs readily Both menisci, the infrapatellar fat pad and all accessible diseased tissue are removed Next, with a fine osteotome a curved resection of the articular cartilage of both the condyles of the femur is performed likewise the condyles of the tibia are denuded of cartilage so that there is good contact between the femoral and the tibial condyles Extensive resection of all diseased bone is not essential, only enough bone should be removed to permit satisfac

deses are the ideal operations, the intra articular arthrodeses are by far the most popular In 1933 Delahaye described for the first time an extra-articular operation. He employed a long flexible tibial graft, which was inserted through the substance of the patella and bridged the interval from the femur to the tibia This principle was utilized by Richards and King who devised a two-step procedure In the first step a tibial graft was inserted in the patella and the tibia in the second, another tibial graft was placed between the patella and the femur The goal of this technic is to achieve spontaneous bony ankylosis of the affected articulation by an extra-articular bridge of bone which eliminates all motion in the joint In spite of the theoretical advantage of extra-articular arthrodeses, they are used rarely however they may come into greater favor in the future.

Intra-articular Arthrodeses. The objective of all arthrodesing procedures is to obtain a bony ankylosis of the knee joint. This is achieved best by fulfilling specific technical requisites These are adequate and accurate bone contact between the femur and the tibia prolonged and effectual fixation until fusion is achieved and bone struts across the joint line to promote osteogenesis Those procedures which meet all the aforementioned requirements are known to have the highest incidence of successful results while those that do not have fallen into disuse because of the poor results that ensued In order to assure undisturbed fixation some surgeons use screws and pins across the joint line This practice must be discouraged particularly in tuberculous knee joints because of the danger of secondary infection ring sequestri and other unfavorable complications Fortunately clinical experience has amply proved this point hence today less and less foreign material is introduced across joint lines of tuberculous knees On the other hand the principle of compression is a valuable adjunct in promoting rapid osseous union and shortening the time of immobilization The author utilizes this method routinely in all fusions of the knee if no contraindications to its use exist

Arthrodesing operations fall into four categories (1) arthrodeses with bridging grafts (2) arthrodeses by resection and compression (3) arthrodeses with internal and external fixation and (4) arthrodesis by a combination of the above methods

Arthrodesis With Bridging Grafts The earlier operations depended solely on the bridging grafts to effect a bony ankylosis The articular surfaces of the joint are not resected. Although these procedures are executed with minimum shock and trauma and result in no shortening of the limb the incidence of failure to obtain a bony fusion is higher than in arthrodesing operations in which resection of joint surfaces is carried out hence, they are seldom used Hibbs original operation used the patella as a bridging graft, while Putti utilized a triangular wedge of bone removed from the upper end of the tibia, including the tibial tubercle. Roeren described a rotation arthrodesis which was modified by Milgram however, this procedure is not recommended for tuberculous joints Hibbs later procedure which included curved resection of the articular surfaces is widely used. This together with the element of compression is the author s preference It is the operation of choice in tuberculosis of the knee joints of children because it minimizes the amount of shortening of the limb Particular precaution must be taken in children not to inflict trauma to the epiphyseal cartilage plate In adults more resection of the bone ends is usually necessary in fact a modified plane resection is done before the desired plane of contact between the femur and the tibia is reached. Plane resection produces more shortening than curved resection but this is unavoidable in extensive destructive lesions in adults

Hibbs Operation (Modified) A L-shaped skin incision is made beginning on the

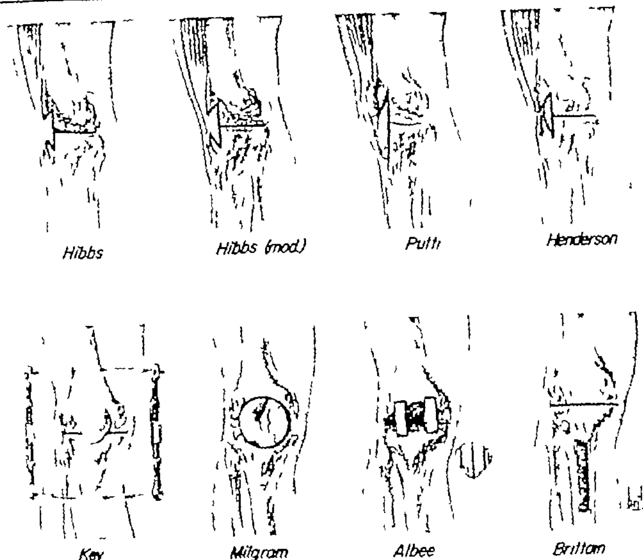


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Hibbs Operation (Modified) A U-shaped skin incision is made beginning on the

flaps on the anterior surface of the femur and the tibia Further stability of the bone ends is achieved by approximating snugly the aponeuroses of the vasti and the capsule with interrupted sutures

Albee's Operation This procedure is similar to the technic of Henderson, except that no nails are used for internal fixation (Fig 409) The patella is excised and denuded of all soft tissue and cartilage With a twin blade saw two grafts are cut out of the patella A slot is made in each femoral condyle, and a corresponding slot is chiseled out of the upper end of the tibial condyles The raw surfaces of the femur and the tibia are approximated, and with the limb held in the position of election, the patella grafts are driven in the slots made in the femur and the tibia. These grafts provide fixation and osteogenesis

Putti's Operation Like the original Hibbs technic, this procedure attempts to attain an osseous ankylosis between the femur and the tibia without resection of the articular ends of the bones (Fig 409) As noted previously, it preserves length of the limb but the incidence of successful fusions is not as high as in procedures which resect the articular surfaces.

The knee is exposed through an anteromedial incision, and the patellar tendon is detached from the tibial tubercle A triangular-shaped piece of bone is removed from the anterior surface of the tibia the base of the triangle is at the upper border of the anterior surface of the tibia, while its apex is at the lower margin of the tubercle of the tibia A flap of bone is elevated from the anterior surface of the femur Next the tibial graft is turned around and its apex is inserted under the osseous flap on the anterior surface of the femoral condyles, while its base rests on the raw surface on the anterior surface of the tibia. In addition, the articular cartilage is removed from the patella, and the raw surface is brought in contact with the corresponding raw surfaces made on the osseous flap of the femur The patella and the tibial graft are anchored by catgut sutures, one passing around the flap and another around the base of the tibial graft

Brittain's Operation The advantage of this procedure is that fixation is achieved with healthy tibial grafts which stimulate osteogenesis (Fig 409) It is contraindicated in children, because the grafts will traverse the epiphyseal cartilage plates thereby inducing growth disturbances in the form of axial deformities and shortening of the limb

An anteromedial incision is utilized to expose the knee joint The lower limb of the incision continues distally 6 inches on the crest of the tibia. The crest and the adjacent anterior surface of the tibia are exposed subperiosteally, and two parallel grafts 5 inches in length are removed with a motor-driven saw The grafts include the crest of the tibia It is advisable at this time to close the lower limb of the incision in order to prevent contamination by material from the knee joint The patella is excised from its bed, and with a twin blade handsaw parallel cuts are made through the articular ends of the femur and the tibia. Wide thin osteotomes are used to complete the resection A special chisel or Henderson reamer is passed through the anteromedial aspect of the base of the medial tibial condyle it is directed upward and outward, passing through the tibia across the joint line and into the femur the chisel is left in place A second chisel or reamer is inserted into the anterolateral aspect of the base of the lateral condyle and directed upward and into the femur The first chisel is removed, and a graft is driven in its track then the second chisel is withdrawn, and the remaining graft is inserted At the completion of the operation the raw areas of the femur and the tibia should be in good apposition, and the limb in the desired angle of flexion at the knee

Arthrodesis With Iliac Bone. To provide stability and osteogenesis knee fusions may be augmented by iliac grafts This source of bone is readily accessible, and as

tory contact of the raw surfaces of the femur and the tibia. The lateral collateral and cruciate ligaments are left intact. Transverse slots are chiseled out of the anterior surfaces of the femur and the tibia and by extending the knee the patella is mortised into the slots The severed ends of the patellar tendon and the capsule are brought together by interrupted sutures Immobilization of the extremity is attained by a single plaster spica from the waist to the toes Children s knees are placed in full extension (180°) in order to overcome the tendency to develop flexion deformities or slipping of the distal femoral epiphysis The adult knee is allowed to fuse in 10° to 20° of flexion this facilitates walking and sitting

Galloway s Operation This procedure is seldom used It comprises a plane resection of the articular surfaces of the femur and the tibia use of lateral bridging grafts and 4 transfixing nails The modern trend to avoid the use of cross pins or nails across the joint line in tuberculous knees has been substantiated by the unfavorable sequelae reported in cases where such material has been used The compression method used by the author to induce rapid fusion and maintain the position of election of the knee is accompanied by fewer hazards than internal fixation by transfixion pins

As in the Hibbs procedure the knee is exposed by a U-shaped incision All accessible diseased tissue is removed also the menisci and the infrapatellar fat pad are excised A flat layer of bone is elevated from the lateral aspects of each condyle of the femur these will function as bridging grafts corresponding raw surfaces are created with a thin osteotome on the lateral aspects of the tibial condyles With a saw the articular ends of the femur and the tibia are resected so that when approximated the knee will be flexed 165 Likewise the articular cartilage of the patella is removed and a raw surface is made on the anterior surface of the femur and the tibia Next the surfaces of the femur and the tibia are brought into contact and fixed by 2 wire nails or Knowles pins which are introduced through the tibia into the femur in such a manner as to cross each other Two other nails fix the patella to the femur and the tibia the patella also bridges the joint line. Finally, the lateral flaps of bone elevated previously from the condyles of the femur are fitted across the joint line and approximated to the corresponding raw surfaces on the lateral aspects of the tibial condyles

Henderson s Operation This operation (Fig. 409) is a modification of Galloway s procedure The knee joint is exposed by a U shaped incision and the large flap containing the patella is reflected upward The patella is excised and denuded of all tendinous attachments periosteum and cartilage it is used later as a free graft. As nearly complete a synovectomy as possible is done A plane resection of the ends of the femur and the tibia is performed by a saw Now the tibia is readily displaced forward and as much of the infected synovial membrane in the posterior region of the joint as is accessible is removed Sufficient bone is removed from the condyles to permit approximation of the bone ends at the angle of election this excised bone is set aside to be used as grafts About 12 cm. below the proximal border of the tibia 2 small incisions are made on each side of the mid line through which 2 wire nails are inserted The nails are directed upward and backward passing through the tibia until their ends protrude from the resected tibial surface A layer of bone from 2 to 3 cm in length is elevated from the anterior surface of the femur a similar flap is pried from the corresponding anterior surface of the upper end of the tibia The resected ends of the femur and the tibia are brought together and held at the desired angle of the knee joint This position is secured by driving the nails into the femur The patella or the cancellous bone obtained previously from the femoral condyles is mortised under the bone

flaps on the anterior surface of the femur and the tibia. Further stability of the bone ends is achieved by approximating snugly the aponeuroses of the vasti and the capsule with interrupted sutures

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Arthrodesis With Iliac Bone To provide stability and osteogenesis knee fusions may be augmented by iliac grafts This source of bone is readily accessible and as

many grafts as are desired may be obtained moreover the bone in this region is free of infection and its use eliminates the unfortunate sequel of a fracture of the tibia following the removal of massive grafts

ARTHRODESIS WITH COMPRESSION The value of compression forces in arthrodesing operations has not been fully understood until very recently, following the publication of Charnley in 1948 The method was first described by Key in 1937 several modifications of this technic have appeared in the literature since its introduction. As noted previously it provides adequate fixation without inserting pins nails or screws across the joint line in diseased bone and more important it is a powerful stimulus of osteogenesis

Key's Operation The joint is exposed through an anteromedial or U-shaped incision the latter is employed more commonly (Fig 409) The upper flap containing the patella and the patellar tendon is reflected upward permitting access to the articular surfaces and other structures in the anterior compartment of the joint As a rule all the diseased synovialis which is accessible is excised also the infrapatellar fat pad and the menisci are removed Gross osseous foci of the disease are curetted Next a curved resection of the articular surfaces is performed with a sharp thin osteotome or a plane resection is done with a saw forming two flat surfaces The amount of bone removed should not be excessive because too much shortening will result only enough bone should be resected to allow good apposition of the raw surfaces Care is taken not to injure the epiphyseal plates The planes of resection are such that all axial deformities are corrected the patella is excised and used as a free graft or discarded or it is denuded of its articular surface and brought into apposition to corresponding raw areas on the anterior surface of the femur and the tibia hence acting as a bridging graft

A stainless-steel pin (3/16 inch for adults and 5/32 inch for children) is inserted through the lower third of the femur an other is passed through the upper end of the tibia The pins are parallel with each other and lie at a distance from the operative field The wound is closed, and a plaster cast is applied from the toes to the groin incorporating the pins After the plaster has hardened a circular section is removed at the knee and extended turnbuckles are fitted to the ends of the pins the turnbuckles are tightened sufficiently to bend slightly, the pins thereby creating a positive pressure at the line of contact of the raw surfaces Repeated tightening of the turnbuckles is necessary to maintain the desired degree of pressure. As a rule, osseous union is sufficient to allow removal of the pins after 8 weeks, another plaster cast is applied and worn for 8 more weeks before weight bearing is permitted Great pressure is possible with this method excessive pressure causes bone necrosis at the line of contact and this must be avoided on the other hand mild pressure is a great stimulus to osteogenesis

The following modification of the above technic is employed by the writer Stainless-steel pins (for adults 3/16 inch and for children 5/32 inch) are inserted parallel with each other through the lower third of the femur and below the condyles of the tibia at a distance from the field of operation. The pins are inserted after the incision has been closed. A plaster cylinder is applied from the groin to the toes incorporating the pins After the plaster has hardened rectangular slots are cut out of the plaster cylinder so that the ends of the pins and the intervening skin are free Stout rubber bands are passed around the ends of the pins, and sufficient tension is created to bend the pins slightly toward one another (Fig 410) Now positive pressure exists between the raw bony surfaces of the femur and the tibia. In nontuberculous joints excluding Charcot's joints constant pressure is maintained for 5 weeks as a rule there is roentgenographic evidence of osseous union at the end of this period. Then the pins are removed and another snug plaster cylinder

applied This is worn for 4 to 6 more eeks during that time the patient is per itted to bear weight on the extremity In berculous and neurotrophic (Charcot) ints positive pressure is maintained for weeks At the end of this period there is ually sufficient clinical and roentgeno aphic evidence of osseous union to permit moval of the pins A cylinder case is ap ied, and weight bearing is permitted In ildren the extremity is protected with a ace for 1 to 2 years in order to prevent pping of the lower femoral epiphysis lults also wear a brace following the re oval of the last plaster cast it is removed ly after the roentgenograms exhibit well rmed continuous bony trabeculations idging the femur and the tibia It may be cessary to wear the brace a year or more

In tuberculous knee joints as in the shoul r joint compression ensures bony union id decreases the period of immobilization oreover, it holds the position of election the limb and prevents backward displace ent of the tibia on the femur

In the author s series there are 8 cases of harcot s knee joints All were treated by e compression method described above, id all achieved a solid bony ankylosis

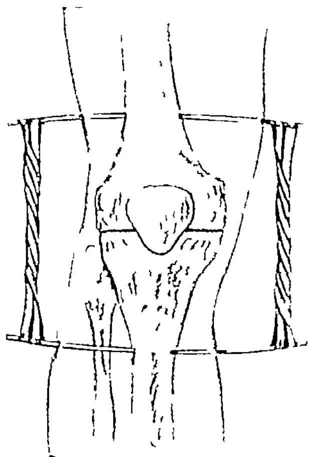


Fig 410 (A) Compression arthrodesis of the knee joint. Constant pressure is maintained at the points of con tact on the bone ends by stout rubber bands passing around the ends of the pins

Arthrodesis for Nontuberculous Affections of the Knee Joint

The technics described for arthrodesis of e tuberculous knee joint are equally appli ible to nontuberculous affections requiring osseous ankylosis of this articulation However several operations have been designed especially for nontuberculous affections and are contraindicated in tuberculosis of the knee joint

Milgram s Operation (Fig 409) This



Fig 410 (B) After the arthrosing operation is completed, a plastic cylinder is applied After the plaster has hardened rectangular slats are cut out so that the ends of the pins and the intervening skin are free. Compression is made by stout rubber bands or tubing passed around the pins as depicted herein.

operation is a modification of the rotation arthrodesis of Roeren first described in 1929. The advantages of this procedure is that it causes no shortening of the limb. It is particularly suitable for osteoarthritis and traumatic arthritis of the knee requiring fusion; however, Milgram has used it in cases of tuberculosis of the joint in adults. It is contraindicated in children because of the damage it inflicts on the epiphyseal plates. *The writer is of the opinion that it never should be used in tuberculous joints.*

A U-shaped incision exposes the articular surfaces of the tibia and the femur. The upper end of the tibia is exposed for a distance of 1 inch. After the menisci, the infrapatellar fat pad and the anterior cruciate ligaments are excised, as much of the implicated synovialis as is accessible is removed; the cavitation in the bones is curetted and the patella is excised. A circular section of bone is removed from the joint, one half is taken from the femur and one half from the tibia. This is done by a special circular saw and curved chisels; the saw consists of a rotating cylindrical cup 1¼ inches in diameter; it is made of crucible steel. The handle of the instrument is of special design. It contains a well into which fits a cylindrical post ¼ inch in diameter and the post is of such length that it projects ⅛ inch beyond the teeth of the circular saw. At the end of the post is a malleable transverse plate which can be curved at operation so as to slip between the articular surfaces and rests on the posterior cruciate ligament. After the anterior cruciate ligament is excised, the post is inserted between the articular surfaces with the malleable plate resting against the posterior cruciate ligament. Next, the cutting cup is fitted over the post and rotated forward and backward to the depth permitted by the post; the instrument is withdrawn and the semicircular grafts are removed with curved chisels; the grafts are cleaned of all soft tissues. They are rotated 90° and reinserted into the circular defect in the joint. Now the joint line between the semicircular grafts lies in a vertical plane at right angles to its former position. All accessible cartilage is removed from the surfaces of the femur and the tibia.

Intramedullary Pinning for Arthrodesis. The principle of intramedullary pinning of diaphysial fractures has been applied to arthrodesis of the knee joint by Chapchal of Holland. He records many advantages of this method over those described previously. Intramedullary pinning provides postoperatively a limb so stable that no plaster fixation is necessary; the position of election is secure unless forces sufficient to bend or break the pin are applied to the region of the knee; postoperative management is simplified and shortened; the patients are able to walk from the first day they leave the bed; physical measures to maintain muscle tone and function in the remaining joints of the extremity are readily employed when no plaster envelops the limb. In addition, decubitus ulcers, circulatory disorders of the limb and paralysis of the peroneal nerve are eliminated. Chapchal advocates this method for all indications for an arthrosis of the knee except in inflammatory disease and in growing children. Osseous ankylosis is usually complete in 4 to 6 months, at which time the pin is removed.

A straight mid line incision from 10 to 12 inches in length is made over the ventral surface of the knee; the patella is excised and the joint is exposed. After the ligaments of the knee are severed the joint is flexed in order to gain access to the articular ends of the femur and the tibia. With a thin osteotome the articular cartilage and the subchondral bone are removed from the femoral and the tibial condyles until satisfactory apposition of the raw bony ends is achieved. A hole 3 cm. long is made in the vertical axis of the femur in the upper end of the incision. A medullary pin as thick as the medullary cavity of the tibia will permit and from 25 to 30 cm. in length is introduced in the hole of the femur and directed downward into the medullary cavity. At

this point care should be taken not to fracture the shaft of the femur while inserting the pin When the distal end of the pin pierces the surface of the femur the tibia is placed in front of it so that the pin will enter the medullary canal of the tibia, this is possible only when the knee is flexed from 6° to 10° Different angles of flexion can be obtained by changing the point of entrance of the pin in the femur The wound is closed in the usual manner

No plaster cast is applied after the operation after 10 to 14 days the patient is allowed to bear weight and uses a removable plaster splint, which is worn only when walking and is taken off when resting Depending upon the occupation, the patient is ready to resume work after 3 or 4 more weeks

Arthrodesis by Central Bone Graft (Hatt) The use of a central bone graft in arthrosis of the knee joint provides immediate stabilization of the limb in the position of election, eliminates the use of metal as agents of internal fixation and favors rapid osseous ankylosis Key described such a method in 1937 he used a large central autogenous bone peg Theoretically, it should be reserved for adults with nontuberculous affections of the knee however Hatt has employed a similar method in children with tuberculous knee joints and records no increase in the amount of shortening when compared with a similar group of cases in which the Hibbs' procedure was performed The average shortening in both groups of cases after an average follow up period of 7 years was approximately 1 inch The average age at the time of operation in both series was slightly over 9 years Dissemination of the diseases along the tract of the graft did not occur in any instances.

The knee joint is exposed through a linear anterior incision the lower limb of the incision is carried distal to the junction of the upper and the middle thirds of the tibia. The patella is freed from the quadriceps femoris above, this is done in order to prevent upward displacement, which occurs frequently when the muscle attachments remain intact. A plane-curved resection of the ends of the femur and the tibia is done with a saw or an osteotome, and the raw ends are approximated Next the upper third of the tibia is exposed and a transverse cut is made immediately distal to the tubercle of the tibia. A graft measuring 1½ by 12 cm. is removed with a motor saw or osteotome A specially designed osteotome is driven upward starting in the graft bed crossing the joint line and penetrating deeply in the substance of the femur The alignment is checked carefully, and necessary adjustments are made at this time The osteotome is withdrawn and the graft is driven into the tunnel this is facilitated by a bone set shaped similarly to the osteotome Finally, the patella is divested of cartilage and placed across the joint line, functioning as a bridging graft. The wound is closed in the usual manner, and a plaster cast is applied from the groin to the toes

Bosworth's Operation. The knee joint is exposed through a U shaped incision the medial limb of the incision is extended upward proximal to the condyle of the femur After the articular surfaces are denuded of cartilage and shaped to fit properly, the bones are fixed in the position of election (which is with the knee straight) by a Smith Petersen nail The nail is driven obliquely downward and outward through the medial condyle of the femur and into the substance of the tibial condyles The posterior two thirds of the patella is removed leaving a flat surface which is approximated to corresponding surfaces on the outer surface of the femur and the tibia, it is fixed to the tibia by a screw placed obliquely and now functions as a bridging graft.

Arthroplasty of the Knee Joint

Historical Survey Arthroplasty is a reconstructive procedure designed to restore motion in ankylosed or stiffened joints This is achieved by remodeling the affected articular ends and by re-establishing the func

tional mechanics of the articulation which in a large measure are governed by the ligamentous and muscular apparatus of the joint The intense desire of the earlier surgeons to restore motion in a fused or defective joint was responsible for the numerous attempts in joint resection In general joint resection failed to produce the desired results because of the many failures resulting from instability of the joint if too much bone was resected or recrudescence of the osseous or fibrous union if less bone was removed To Rhea Barton (1826) of Philadelphia goes credit for performing the first arthroplasty He succeeded in establishing a pseudoarthrosis in an ankylosed hip joint The operation performed was not a true arthroplasty instead it was a high osteotomy through the greater trochanter and part of the femoral neck he prevented osseous union by repeated passive motion The result was a stable weight bearing limb with motion at the osteotomy site Motion was still demonstrable 2 years after operation then ankylosis recurred The next logical step in the development of arthroplasty was the interposition of materials between the articular surfaces to prevent osseous or fibrous ankylosis and thereby allow some permanent mobility

The first attempt at interposition of soft tissue between the remodeled bone ends was made by Ollier (1884) he used adipose tissue which lay loosely within the joint space The results were discouraging because the tissue was absorbed readily and osseous union or fibrous ankylosis ensued Experiments utilizing other soft tissues followed Helferich in 1893 and Mikulicz in 1895 attempted to prevent fusion of the resected bone ends by interposing muscle flaps taken from areas adjacent to the joint Although the immediate results were better than those of Ollier eventually the muscle flaps were absorbed and postoperative ankylosis resulted In 1900 Chlumsky published his experiments in animals using different material absorbable and nonabsorbable as interposing media between resected bone ends Such material as plates of zinc rubber, silver and celluloid were tried in the early experiments later he used decalcified bone ivory and magnesium. His work provided the basis for subsequent experiments with foreign interposing materials Many of the nonabsorbable substances were extruded from the joints suppuration was a frequent sequel and in all instances wherein the animal survived recrudescences of ankylosis ensued Autogenous flaps of periosteum (Hoffman Payr and Von Frisch) joint cartilage (Tuffier Klapp Mauclaire) skin (Gluck Tretze) and muscle (Helferich Lentz, Henla Hoffa and many others) were tried as interposing substances Although occasional satisfactory results were attained on the whole the aforementioned substances proved to be inadequate in arthroplasties and have been superseded by free transplants of fascia lata. Murphy (1902) again investigated the use of pedicle flaps and designed arthroplasties for all the major joints His enthusiasm and success were powerful stimuli to other workers interested in this field Murphy was a strong advocate of the use of autogenous fascial membrane the most common source being the fascia lata of the thigh or from fibrous structures in the vicinity of the operated articulation The advantages of these structures over foreign metallic material or heteroplastic substances soon became apparent nevertheless Robert Jones (1902) performed a successful arthroplasty of the hip using gold foil as the interposing agent The patient still has a useful range of motion 21 years after the operation Lexer also favored the use of autogenous fascial membranes yet he attempted the transplantation of articular ends of homoplastic bones The results were either total failure or far from satisfactory

The intensive investigation in arthroplasties by such surgeons as Lexer Putti Payr and Enderlen in Europe and in this country by Murphy, Baer Allison MacAusland Henderson and Campbell resulted

in perfecting the surgical technics and in establishing the indications and the counter indications of the procedure In 1925 Smith Petersen introduced the use of the prefabricated mold as an interposing substance after considerable experimentation, the alloy vitallium, first used in surgery of bones by Venable and Stuck was selected because of its nonelectrolytic nature. The use of the vitallium cup in arthroplasty of the hip was first reported by Venable and Stuck and by Hopkins and Zuck in 1938 Within the past decade further advancement has been made by the introduction of prostheses, replacing one of the articular ends of the bony components of the joint. Judet popularized the use of a plastic prosthesis for the femoral head The acceptance of this work is reflected in the numerous prostheses which have been designed for the femoral head and neck Each one has some mechanical features believed by the originators to be of special value the most popular materials used are inert plastics, vitallium and stainless steel The true value of replacement by prefabricated prostheses can be determined only after the method has been tried in a large number of cases and a sufficient period of time has elapsed (5 to 10 years) Experiments in replacement of bone ends of other joints such as the head of the humerus, are also being conducted. The many good immediate results reported in the literature indicate that we may be on the threshold of a new era in the field of arthroplasty

Evaluation of Interposition Materials and Prostheses. It is generally accepted that fibrous and osseous union between the raw surfaces of a newly remodeled joint is less apt to occur if some interposing substance is present Furthermore, clinical experience reveals that interposition of soft tissue such as muscle, fascia and fat between the fragments of fractured bones may induce nonunion or even a pseudoarthrosis In addition Brooks and Allison demonstrated experimentally that denuded bone ends exhibit a covering of granulation tissue arising from the marrow spaces at the end of 5 days. This is the basis of the subsequent development of a fibrous ankylosis and later osseous union This sequence can be interrupted by interposing substances of soft tissue which tend to prevent the formation of fibrous strands extending from one raw surface to the other It becomes apparent that the chief function of autogenous interposing material is to prevent the formation of fibrous adhesions until a dense fibrous covering is formed over the bone ends which is derived from the granulation tissue growing out of the marrow spaces Eventually, the interposing substances are absorbed completely Function of the joint stimulates the formation of a mature connective tissue covering the process is one of physiologic repair

As stated previously, many materials have been used to preserve motion in a reconstructed joint among these were glass, gold and tantalum foil, celluloid ivory pegs and chromicized pig's bladder These have failed to produce the desired results and have been replaced by autogenous fascial membranes and inert metals such as stainless steel and vitallium more recently inert plastics have been introduced.

Fascia Lata. The advantages of the use of free transplants of fascia lata is well established, it is by far the most commonly employed interposing medium in arthroplasty It is utilized in arthroplasty of all joints, large and small However, since the introduction of inert materials it has been used less frequently in arthroplasties of the hip Many surgeons prefer the prefabricated vitallium cup as a covering over the femoral head The free transplants of fascia lata are removed from the lateral aspect of the thigh, where a sheet of the material large enough to envelop any raw surface may be procured Some surgeons interpose a single sheet of fascia between the raw bony ends the writer prefers two layers By so doing free gliding of one surface on the other is assured The outer surface of the fasci differs from the inner surface, t

surface is coarse and consists of fibers less compact than the inner surface which is *smooth glistening and composed of compact* fibrous strands The outer surface is placed next to the raw bone to which it adheres readily because of its loose coarse texture while the smooth undersurface now lining the interior of the joint enhances motion

PEDUNCULATED FASCIAL FLAP This method is rarely employed The flap comprises fascia and fat obtained in the vicinity of the joint to be reconstructed Its use is indicated only in instances wherein fascia lata is not available and in isolated cases of ankylosis of the patella to the femur but with free motion between the femur and the tibia The author utilizes this technic in operations for recurrent subluxating or chronic dislocation of the patella and also in cases of chondromalacia wherein the articular surface of the patella is removed a flap of infrapatellar fat pad is dissected free and placed over the raw undersurface of the patella In general soft tissues adjacent to a defective joint exhibit pronounced fibrosis making it undesirable as an interposing substance Moreover in most instances the remaining attached pedicle is too deficient in blood supply to be of any substantial aid in the nutrition of the dissected flap after its transplantation.

FREE FAT Transplants of *fascia lata have* replaced completely those of fatty tissue obtained at a distance from the joint

VITALLIUM This material is universally accepted as an excellent interposing agent It was first introduced by Venable and Stuck but its use as a prefabricated mold in arthroplasties of the hip was popularized by Smith Petersen Campbell designed a vitallium mold for the remodeled end of the femur in arthroplasties of the knee He reported 4 cases all were graded as poor results so the method was discarded Further experimentation with vitallium as an interposing material in the knee and other joints might reverse Campbell s unsatisfactory results More recently vitallium stainless steel and inert plastic prostheses particularly for the head and the neck of the *femur have been introduced* This new approach in arthroplasties attempts to eliminate vitallium as an interposing material

Critical analysis of long range follow-up studies is necessary *before judgment* can be passed on the validity of the prostheses

Structural and Morphologic Alterations in Reconstructed Joint. Information relative to the histology of arthroplasties is limited and difficult to procure Animal experiments in this field have been of very little significance because ankylosis in joints of animals is rarely encountered and it is not possible to produce in animals conditions analogous to the pathologic processes found in ankylosis of the human joints moreover it is impossible to obtain from animals the intelligent concerted effort essential to the evaluation of functional adaptation of an articulation Hence the work of Murphy Sumita Neff Putti Segale Allison and Brooks Phemister and Miller done on animals adds little to our knowledge of this problem

Observations of value were made by Baer MacAusland Campbell and Putti These workers studied and recorded in detail the anatomic morphologic changes in joints following arthroplasties at secondary opera*tions and from reconstructed joints obtained* postmortem The observations relative to the fate of the fascia lata when used as an interposing membrane were of special significance Summation of their findings permits the following conclusions to be made (1) Arthroplasties executed skillfully produce new joints with a useful range of motion good stability and no pain (2) A joint cavity is re-established which is usually smaller than the normal cavity and it may be multilocular (3) A joint fluid simulating synovial fluid lubricates the joint (4) During the early months following the operation the articular ends of the bones are covered by a layer of dense fibrous tissue which represents the fascia lata altered by

functional adaptation (5) With increased function and passage of time the aforementioned superficial connective tissue stratum is replaced by fibrocartilage which arises in part from the marrow spaces of the bone ends and in part from the remnants of the fascial membrane (6) Immediately below the stratum of fibrocartilage a compact layer of bone is formed in response to function, bone trabeculae reappear and rearrange themselves along the line of stress

Indications and Contraindications for Arthroplasty of the Knee Joint. The indications for mobilization of the knee joint are few because an ankylosed knee in good functional position provides the patient with a stable, painless useful limb This fact makes arthrodesis of the knee joint in cases with limited motion resulting from an incomplete fibrous ankylosis a strong competitor of arthroplasty the same is true of the osteotomy in ankylosed knee joints in malposition Nevertheless there are indications which justify the procedure in spite of the opinion of some surgeons who maintain that an arthroplasty of the knee is never justified if an arthrodesis can be effected with the limb in a good position of function This view is held chiefly by the British surgeons the results of many of the American surgeons do not support this belief Before arthroplasty is performed each case must be studied critically, and specific requisites must be met otherwise the procedure is doomed to failure In most instances the decision is governed by the severity of the disability imposed on the patient by a stiff knee Occasionally, one is justified in mobilizing an ankylosed knee in good functional position if the patient's occupation is expedited by a movable joint Only in rare instances is the operation performed for esthetic reasons yet one must admit that even a stiff knee in an acceptable position of function is a handicap when sitting and is a constant source of embarrassment to young people particularly to women.

Follow up studies of many arthroplasties of the knee by numerous workers reveal that the following general and local considerations are of prime importance in the ultimate success or failure of the procedure

(1) As stated previously the degree of disability that the fused joint causes must be determined Ankylosed knee joints in 10° to 20 of flexion with the ankle at right angles to the lower leg produce little dysfunction of the limb, and arthroplasty is not indicated unless it will facilitate execution of the patient's occupation

(2) Ankylosis of the knee joint in malposition or a knee with restricted painful motion, as is found in incomplete fibrous ankylosis, is an indication for arthroplasty

(3) Two stiff knees or a stiff hip and knee in the same limb justify mobilization of one knee joint

(4) Flexion deformities exceeding 100° increase the technical difficulties of the operation and may preclude a good result In these cases a preliminary osteotomy may be necessary When the operation is done on ankylosed joints approaching the position of function the chances of a successful result are increased In ankylosed knees with a flexion deformity exceeding 120° Campbell performed a two-stage operation In the first stage the union between the tibia and the femur was divided posteriorly, and the deformity was corrected, occasionally a posterior capsulotomy was necessary to attain the desired amount of correction, or in other instances further extension was achieved by traction Then the limb was immobilized in a plaster cast for 6 weeks and weight-bearing was allowed with a brace The second stage, which comprised the actual arthroplasty, was performed after the osseous and soft tissue structures approached normal

(5) Shortening of the limb more than 3 inches, resulting from bone destruction or growth disturbance, is a contraindication to arthroplasty

(6) The etiologic factors responsible for

the ankylosis of the joints play a major role in the final decision of the surgeon (A) The results of arthroplasties performed in ankylosed joints caused by trauma or acute pyogenic infection are superior to those induced by *other factors or varieties of infection.* This is especially true of ankylosis resulting from gonorrheal infection these joints lend themselves readily to arthroplasties (B) Arthroplasty is contraindicated in ankylosed joints of tuberculous origin Recrudescence of the disease following extensive surgery is a real and disastrous probability (C) In ankylosis of both knees or the hip and the knee of the same extremities induced by tuberculosis one is justified in performing an arthroplasty of one knee joint In these cases the seriousness of the dysfunction is so profound that the surgeon is justified in challenging the hazards associated with the reconstructive procedure Today the use of antibiotics and chemotherapy tend to minimize the risk (D) In general arthroplasty is contraindicated in low grade inflammatory processes implicating the collagenous tissues of the body such as in atrophic polyarthritis In these instances it is justified only if there are multiple ankyloses Even when the operation is performed by the most skillful surgeons the prognosis is not good

(7) Proper timing of the mobilizing procedures is essential In ankylosed joints induced by pyogenic infections arthroplasty should not be attempted until 18 to 24 months have elapsed after all evidence of infection has disappeared Surgical intervention before this period is apt to cause recurrence of the septic process Chemotherapy and antibiotics may shorten this period In tuberculous joints the same principle holds here the hazards are present even after a waiting period of several years in spite of the fact that there is no evidence of activity determined clinically and roentgenologically If ankylosed joints caused atrophic arthritis no attempt should be made to mobilize the joints until the inflammatory process has subsided completely On the other hand the waiting period must not be protracted indefinitely because disuse promotes profound atrophy of the soft tissue elements and demineralization of the bony components of the joint Such changes increase the technical difficulties and retard early and satisfactory function of the newly constructed joint

(8) Success or failure of an arthroplasty of the knee depends in a large measure on the condition of the osseous elements the muscles that motorize the new joint, the ligaments that aid in its stability and the surrounding skin (A) Advanced atrophy and demineralization of bone contraindicate surgical intervention Such bone is difficult to reshape to the desired configuration It becomes apparent that in cases of severe osteoporosis and atrophy the bone must first be restored to normal before any mobilizing operation can be considered If the extremity is in a position capable of weight bearing this goal can be achieved by active use however in joints with severe malposition precluding activity first the deformity must be corrected then a regimen of muscular development and weight bearing is instituted to restore normal bony texture (B) Dense eburnated bone implicating the femur and the tibia beyond the joint line is not favorable material for an arthroplasty as a rule such bone is the product of a fulminating osteomyelitic process It is difficult bone to remodel and there is always the probability of re-activating the infectious process by surgical intervention. If the limb is in a position of function arthroplasty i definitely contraindicated if it is in malposition osteotomy through healthy bone is the procedure of choice (C) In cases of long duration and lack of function the femur and the tibia may form one shaft with a common medullary canal The absence of solid bone in the region of the joint line interferes with proper remodeling of the bone ends hence the success of the arthroplasty is lessened In exceptional cases ar

throplasty may be done, if good muscle control and a stabilizing ligamentous apparatus exist. (D) Advanced muscle atrophy precludes a successful arthroplasty The extent of atrophy is in proportion to the period of disease In long standing cases it is profound The quadriceps particularly loses tone and diminishes rapidly in volume If possible, muscle control must be restored by active contraction and weight bearing before an arthroplasty is contemplated No arthroplasty should be attempted until the extensor muscles of the thigh are in optimum condition To ensure good muscle control progressive muscle exercises against resistance should be practiced for several months before the knee is mobilized If the deformity of the knee prevents weight bearing the malalignment must be corrected first Muscle atrophy parallels osteoporosis and atrophy of the bony elements (E) Excessive scar tissue and fibrosis implicating the skin and the subcutaneous tissue around the knee constitute formidable contraindications to arthroplasty Such conditions are encountered following extensive burns in the region of the knee and in the presence of draining sinuses that have existed for long periods of time the skin may be leathery in texture and adherent to the underlying bone. Normal skin with adequate fat and subcutaneous tissue must be present to ensure a successful arthroplasty If absent it must be restored before the operation is undertaken

(9) According to MacAusland, the preferable age to perform an arthroplasty is between 20 and 40 years, however, in exceptional cases *if all other requirements are fulfilled* it may be performed *in persons* over 40 In children, the danger of injury to the epiphyseal cartilage plate is a strong contraindication to arthroplasty operation should be postponed until epiphyseal growth has *terminated*

(10) Other major considerations determining whether or not an arthroplasty is justifiable are the social status the occupation and the temperament of the patient Ankylosed knee joints in the optimum position of function in laborers should not be mobilized such joints are far more serviceable to these individuals than arthroplasties rated as excellent results. Individuals with a low index of pain who are apprehensive and exhibit a nervous temperament are undesirable candidates for this extensive surgical procedure They are not capable of the concentrated effort and perseverance essential in the postoperative phase of the treatment to develop a good functioning joint

Varieties of Ankylosis. The types of intra-articular ankylosis may be grouped into several categories (1) the most frequently encountered is complete bony fusion implicating the patella the femur and the tibia (2) the tibiofemoral joint is free, but a bony ankylosis of the patellofemoral joint exists, this type is rare, (3) the patella is free, but the tibiofemoral is fused (4) only one femoral condyle is united with the corresponding tuberosity of the tibia, whereas the joint space in the remaining one half of the joint is free, (5) ankylosis, complete or incomplete, may be fibrous in nature, and (6) the ankylosis may be partially fibrous and partially osseous, in both (5) and (6) there are varying degrees of destruction of cartilage of the articular surfaces

In cases exhibiting union, fibrous or osseous on only one side of the joint, surgeons may be tempted to perform a partial or hemiarthroplasty However, the experience of Campbell and others reveals that such procedures invariably fail hence a complete arthroplasty should be performed in *all instances* regardless of the normalcy of *a portion of the articular surfaces* The only exception to the above statement is union of the patella and the femur with a normal tibiofemoral joint In this situation one of two procedures may be performed (1) patellectomy or (2) arthroplasty of the patella.

Technics of Arthroplasty Numerous technics of arthroplasty of the knee have

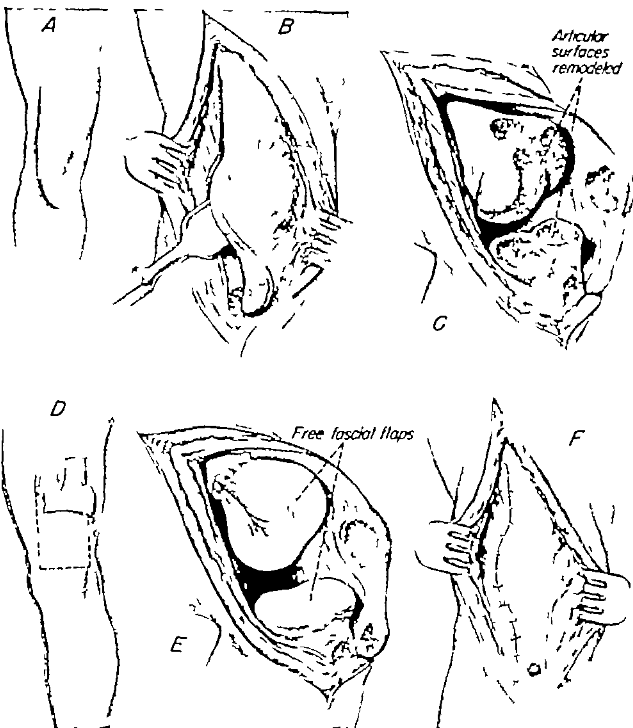


FIG. 411 (A to F) Steps in arthroplasty of the knee joint as descril Either a modified Kocher incision or an inverted U is employed Note th surfaces are shaped to conform to the original contour of the condyles and the plateaus of the tibia All raw surfaces except that of the patella by an interposing membrane (fascia lata)

been designed In general most of them attempt to reconstruct the normal anatomic configuration of the joint They differ slightly in the amount of bone removed from the femoral condyles Some surgeons try to maintain as much normal dimensions of the c in the transverse and the whereas the tibia is excavated to the shape of the femoral c

restore the anatomic curve of the condyles of the femur but decrease sagittal diameter finally, others recreate a flat tibial plateau, and the femoral condyles are pointed A critical survey of the end results reveals that Putti had the highest incidence of satisfactory arthroplasties, however it also becomes apparent that, regardless of the technic employed, the skill and the experience of the surgeon are major factors in the low or high percentage of successful arthroplasties.

TECHNIC OF PUTTI (Fig 411) Putti exposed the joint through a modification of the Kocher incision, which was prolonged distally to a point below the tibial tubercle and then continued around the tubercle, or an inverted U incision which encircles the patella from above to this was added a vertical limb extending upward from the curve of the U Putti's objection to the Kocher incision was the detachment of the tibial tubercle necessary to mobilize the patellar tendon he contended that this step might lead to nonunion or delayed union A portion of the tibial tubercle with the patellar tendon attached is removed with a chisel the patella is detached from the anterior surface of the femur, and the joint is exposed After the ankylosis is freed by chiseling and manipulation, beginning from the outer side the condyles of the femur are remodeled with special chisels with curves that correspond to those of the normal femoral condyles. In the remodeling an attempt is made to preserve as much as possible the transverse dimensions of the condyles whereas their sagittal diameter is decreased Also with specially designed chisels the joint surfaces of the tibia are fashioned so as to approach the normal shape of the tibial plateaus The intercondyloid notch is deepened and the tibial spine is sharpened now the reconstructed surfaces of the femur and tibia should approach the normal configuration of these bones. The final step in remodeling is smoothing the raw surfaces including that of the patella with a file the bone ends are now ready to receive the fascia lata covering A flap of fascia lata 5 to 7 inches in length and 3 to 5 inches wide is removed from the lateral aspect of the opposite thigh The flap is interposed between the newly fashioned bone ends so that it covers the raw surfaces completely the flap is secured by suturing it to the capsule and the periosteum The raw surface of the patella is not covered by a fascial flap when the Kocher incision is used, the detached tibial tubercle is secured to the tibia by a metal nail

An alternate procedure is lengthening of the quadriceps tendon without detachment of the tibial tubercle After the vastus externus and internus are separated from the rectus femoris, the tendon of the rectus femoris is freed from that of the vastus intermedius below and both tendons are divided by Z-shaped incisions in alternate directions This facilitates approximation of the tendons to the desired length at the completion of the arthroplasty Then the incision is carried through the synovial capsule and the lower flap containing the patella is displaced downward providing an excellent approach to all the osseous elements At the termination of the arthroplasty the extensor apparatus is reassembled the tendons of the rectus femoris and the vastus intermedius are united to the proper length the vastus internus and the vastus externus are reattached to the rectus femoris and the wound is closed in the usual manner

TECHNIC OF CAMPBELL (Fig 412) In the arthroplasty designed by Campbell no attempt is made to reconstruct the bone ends similar to the anatomic contours of the femur and the tibia Instead the distal end of the femur is shaped into a single condyle which fits into a corresponding concavity made in the tibia This arthroplasty is predicated on the premise that remodeling of the bone ends to conform to the configuration of the normal joint contributes little to the ultimate stability of the joint. The procedure is modified to meet type and

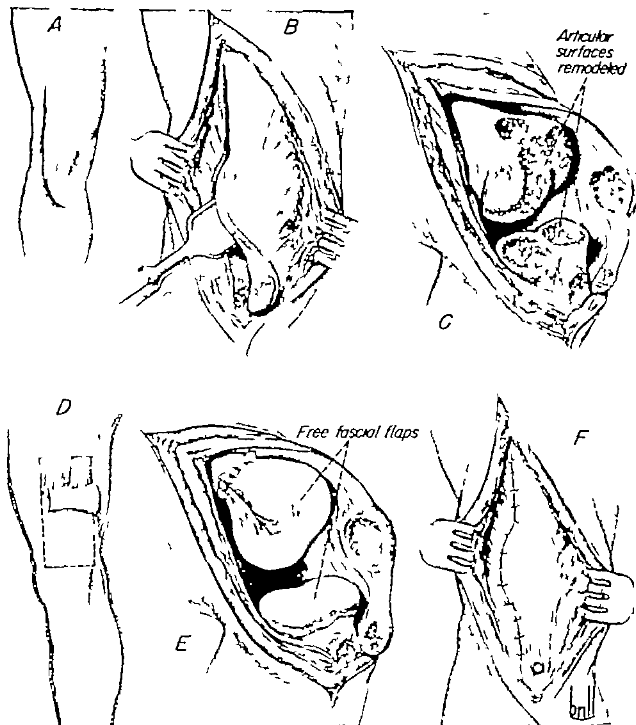


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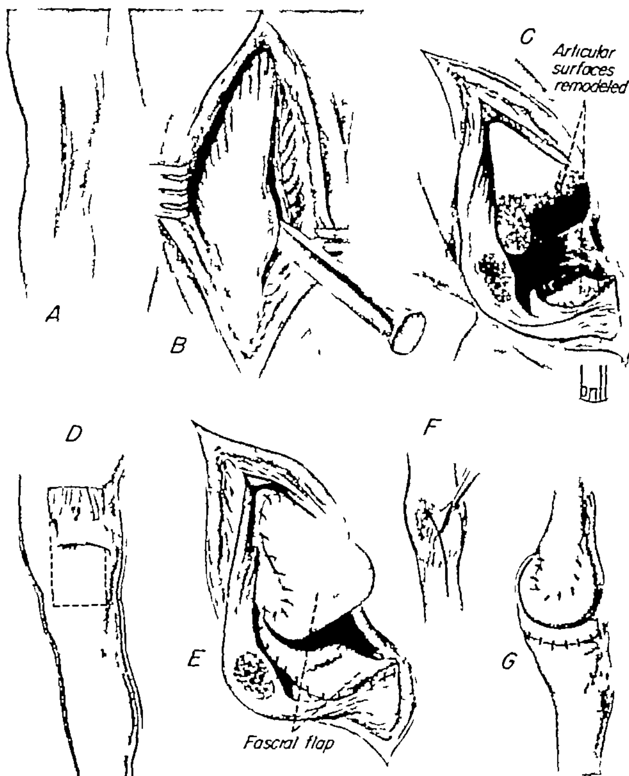


Fig 412 (A to G) Steps in arthroplasty of the knee joint as described by Campbell. The distal end of the femur is converted into a single condyle and the cruciate ligaments and the tibial spine are sacrificed the raw surface of the patella is covered with fat.

distribution of the ankylosis and the position of deformity of the limb present at the time of operation

The skin incision begins from 4 to 6 inches proximal to the joint at the inner margin of the quadriceps tendon it is prolonged downward with a slight convexity directed medially and terminates distal to the insertion of the patellar tendon The superficial and the deep fascia of the thigh are divided in the line of the skin incision and the vastus medialis is separated from the tendon of the rectus femoris which in turn is freed as far as the patella With a sharp osteotome the fusion between the patella and the femur is divided The patellar tendon the patella and the quadriceps tendon are displaced laterally fibrous strands restraining lateral displacement of these structures are severed The femur and the tibia are separated by a thin osteotome in executing this step care must be taken not to divide or traumatize the structures behind the posterior joint capsule By flexing the knee slowly complete visualization of the joint is attained After the posterior portions of the condyles of the femur are removed the distal end of the femur is converted into a single condyle being convex from above downward and from before backward Sufficient bone is removed from the femur to reach cancellous bone removal of too much bone will result in an unstable joint the larger amount of bone is chiseled from the posterior aspects of the condyles With a wide gouge (1½ in) the tibial surface is shaped to single cavity from before back to accommodate the femoral condyle Again as little bone as possible is removed in order to preserve length of the limb After completion of the remodeling traction on the limb should separate the bone ends at least ½ inch. In spite of the loss of the cruciate ligaments in this operation the tibial spine and the supracondylar notch are not reconstructed Stability is dependent entirely upon the broad articulating surface of the femur and good development of the muscular apparatus, especially the quadriceps group Care is taken during the operation to preserve the integrity of the lateral collateral ligaments Finally, the line of approximation of the 2 bones is noted the articulation must be a straight hinge joint hence, if there is any axial deviation at the joint either in varus or valgus, sufficient bone is removed to correct the deformity

The patella is converted into a thin lamina of bone by removing most of its posterior surface in addition approximately ¼ inch of bone is trimmed from its periphery The raw surface is covered by a pedicle flap of fat removed from the posterior surface of the patellar ligament, the edges of the flap are secured to the margins of the tendinous fibers surrounding the patella.

Attention is now directed to coverage of the raw surfaces of the femur and the tibia by an interposing fascial membrane A section of fascia lata measuring from 8 to 10 inches long and from 4 to 5 inches wide is taken from the lateral surface of the opposite thigh. The outer and coarser surface of the fascia is applied next to the bone and the inner surface functions as a lining membrane of the new articular surfaces. The fascia is folded in such a manner that two thirds of its length comprises the upper segment, and one third the lower segment the fold is fastened to the posterior capsule by fine interrupted chromic catgut sutures The upper segment is brought around the femoral condyle from backward to forward and then reflected over the anterior surface of the femur for a distance of 4 to 5 inches the lower segment is brought forward covering the tibial plateau to the anterior margin of the tibia. Finally the edges of the fascia are secured beyond the peripheries of the articular surfaces to the soft tissues and periosteum by a continuous suture of chromic catgut. Occasionally, it may be nec

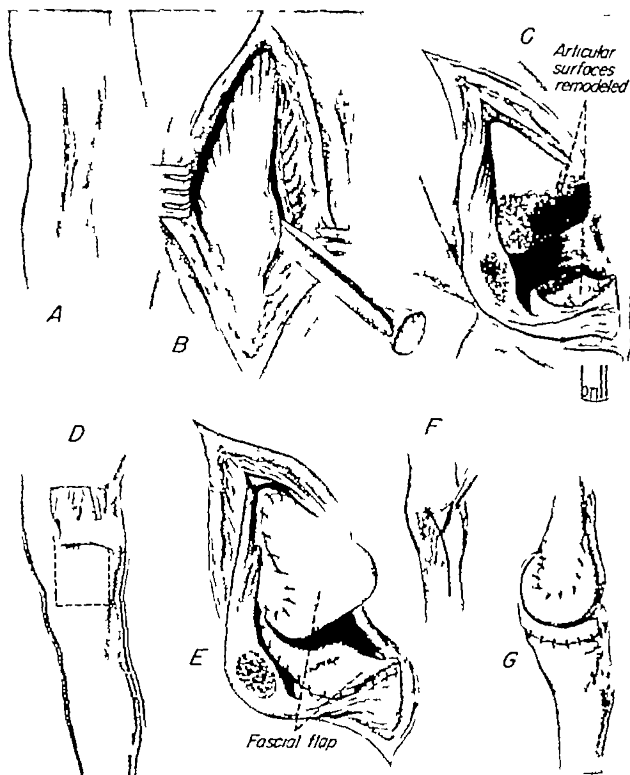


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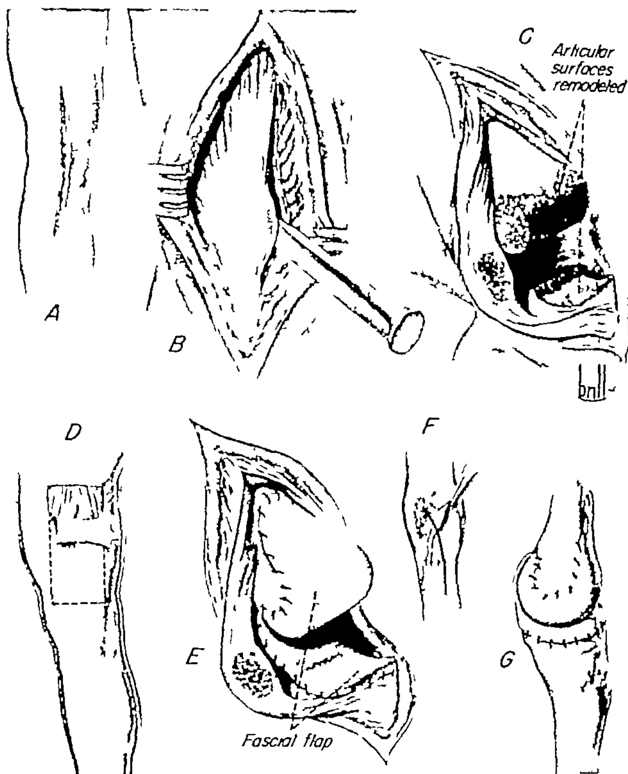


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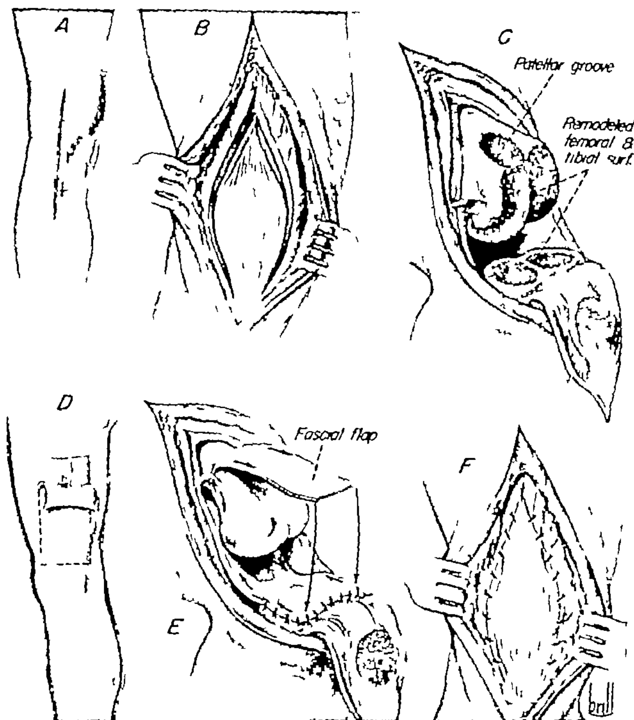


Fig 413 (A to F) Steps in arthroplasty of the knee joint as described by MacAusland. The anatomic contours of the femoral condyles and the tibial plateaus are restored in addition a notch on the anterior surface of the femur is created to accommodate the remodeled patella

essary to anchor the fascia to the margins of the bone by sutures passing through holes drilled in the bone The wound is closed in layers in the usual manner

Technic of MacAusland (Fig 413) This arthroplasty differs from that of Campbell in that an attempt is made to reconstruct the normal configuration of the femur and the tibia also a notch is made on the anterior surface of the femur to accommodate the patella

The skin incision begins from 3 to 4

inches above the patella over the middle of the quadriceps tendon it is continued downward in a straight line over the center of the patella and the patellar tendon and ends 1 to 2 inches distal to the tibial tubercle The skin flaps and the superficial fascia are reflected on each side of the incision for 3 or 4 inches exposing the deep fascia, the quadriceps muscle and tendon An inverted goblet-shaped incision is employed to expose the deeper structures, it begins 3 inches proximal to the base of the patella and extends directly downward for 1 inch, from this point 2 curved incisions, one on each side of the patella continue downward and terminate over the corresponding tuberosity of the tibia the incisions are deepened through the capsule, exposing the intra

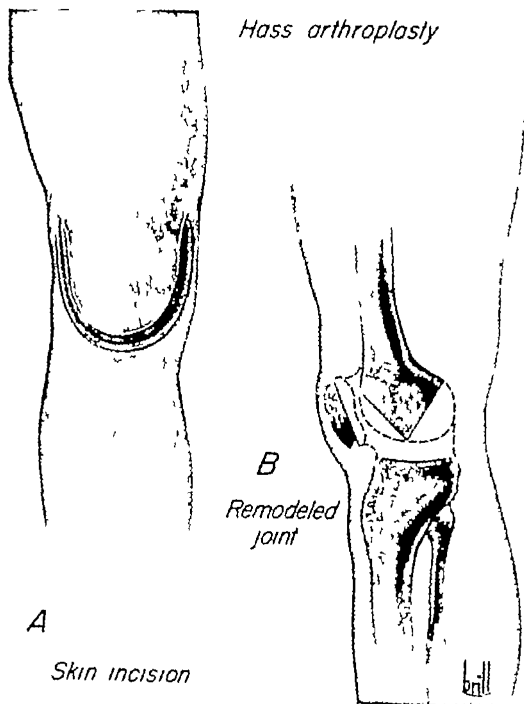


FIG 414 Arthroplasty of the knee joint (Hass) (A) Incision employed, (B) the end of the femur is remodeled into a wedge with a long anterior and a short posterior surface Interposing membrane may or may not be employed.

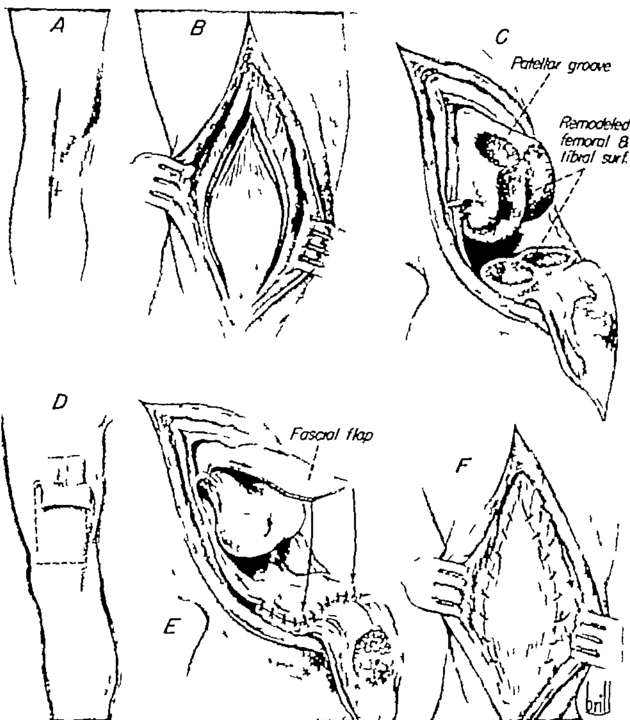


FIG 413 (A to F) Steps in arthroplasty of the knee joint as described by MacAusland The anatomic contours of the femoral condyles and the tibial plateaus are restored in addition a notch on the anterior surface of the femur is created to accommodate the remodeled patella

essary to anchor the fascia to the margins of the bone by sutures passing through holes drilled in the bone The wound is closed in layers in the usual manner

TECHNIC OF MACAUSLAND (Fig 413) This arthroplasty differs from that of Campbell in that an attempt is made to reconstruct the normal configuration of the femur and the tibia also a notch is made on the anterior surface of the femur to accommodate the patella.

The skin incision begins from 3 to 4

inches above the patella over the middle of the quadriceps tendon it is continued downward in a straight line over the center of the patella and the patellar tendon and ends 1 to 2 inches distal to the tibial tubercle The skin flaps and the superficial fascia are reflected on each side of the incision for 3 or 4 inches exposing the deep fascia, the quadriceps muscle and tendon An inverted goblet-shaped incision is employed to expose the deeper structures, it begins 3 inches proximal to the base of the patella and extends directly downward for 1 inch from this point 2 curved incisions one on each side of the patella, continue downward and terminate over the corresponding tuberosity of the tibia the incisions are deepened through the capsule exposing the intra

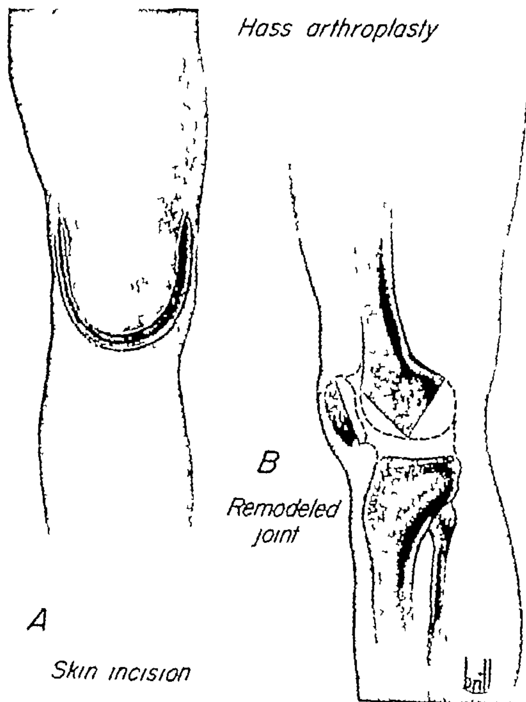


Fig 414 Arthroplasty of the knee joint (Hass) (A) Incision employed (B) the end of the femur is remodeled into a wedge with a long anterior and a short posterior surface Interposing membrane may or may not be employed

articular structures After the patella is freed from the femur the entire flap is turned downward. All ligamentous structures are dissected free from the femur and the tibia but they are left intact

With the use of Putti s chisels the new joint surfaces are remodeled, following as closely as possible the normal contour of the bone ends about 1 cm of bone is removed from the condyles In addition to reshaping the condyles the intercondylar notch is reconstructed Two cavities are chiseled out of the tibial surfaces to accommodate the femoral condyles between them is left a well formed tibial spine which fits in the intercondylar notch and ensures lateral stability On the anterior surface of the femur a shallow cavity is created which will articulate with the patella All surfaces are *smoothed with rasps and files*

Attention is now directed to the patella which is narrowed considerably This is achieved by trimming off longitudinally one third of the inner and the outer surfaces and one third of the posterior surface of the remaining bone Then it is enclosed in the joint capsule.

From the opposite thigh a piece of fascia lata is removed its length and width should be sufficient to cover both femoral condyles both tibial plateaus and the posterior surface of the patella The edge of the flap is first sutured to the anterior and lateral surfaces of the tibia then the flap is drawn into the popliteal space to a point 2½ inches up the posterior surface of the femur and sutured to the posterior capsule next it is drawn upward over the condyles of the femur and anchored around the condyles by a purse-string suture the remaining portion of the flap is reflected downward and sutured to the upper margins of the tibial tuberosities After the quadriceps apparatus has been reassembled the wound is closed in layers

Technic of Hass (Fig 414) In this operation Hass strives to convert the ankylosed knee into the simplest form of ginglymus Primarily, he is concerned with remodeling the new joint from a physiologic rather than an anatomic viewpoint Also, he is of the opinion that an interposing substance is not essential in restoring function but it does serve to fill in the dead spaces in the anterior and the posterior compartments of the joint and acts as a hemostatic agent Technically he reduces the amount of bone contact to a minimum, believing that this feature obviates refusion of the bone ends and allows motion without friction The ultimate configuration of the bone ends is in response to functional adaptation the end of the femur becomes round and smooth and even develops condyles, whereas the trough in the tibia is deepened

The joint is approached through a curved infrapatellar skin incision After the tibial *tuberosity is detached, the patella is chiseled* off the anterior surface of the femur, and the flap containing the tibial tuberosity the patellar tendon and the patella is turned upward exposing the anterior surface of the tibiofemoral joint With thin sharp osteotomes the union between the femur and the tibia is divided In so doing the lateral ligaments are spared By flexing the knee the entire lower end of the femur is made accessible the condyles are removed forming a wedge with a long anterior and a short posterior surface The plateau is reshaped into a shallow trough perpendicular to the femur next the patella is thinned by removing its posterior surface and all raw surfaces are smoothed with a rasp and a mallet As much of the capsular tissue as is accessible is removed and the end of the femur is covered with a layer of fat removed from the lateral aspect of the thigh The tibial tuberosity is made secure to its original site by a metallic screw or nail and the wound is closed in the usual manner Skin traction is applied to the leg and the limb is immobilized in plaster with the knee extended

Technic of Author (Fig 415) Recently the author has designed and employed a vitallium prosthesis for the tibial

plateau, *in addition* the raw surfaces of the end of the femur and the anterior surface of the lower end of the femur are covered by a strip of nylon the raw surface of the patella is covered with fat The results attained are encouraging, but the cases as yet are too few (4 cases) and too recent to allow adequate evaluation of the method Later a critical analysis of the cases will be recorded

The actual remodeling of the bone ends is similar to that described by Hass except that the end of the femur is made less angular, and approximately 1½ cm of the upper end of the tibia is resected

Postoperative Management. Careful supervision of this phase of the treatment is essential, the rapidity of rehabilitation is governed by many factors, such as the duration of the ankylosis, the severity of the existing osteoporosis in both bones, the status of the muscular and ligamentous apparatus and the intelligence and the cooperation of the patient In general, the limb should be put at complete rest after the operative procedure for 2 to 3 weeks This is achieved best by immobilizing the extremity in plaster with the knee extended and adhesion traction to the leg making 4 to 6 pounds pull Total rest ensures rapid ces

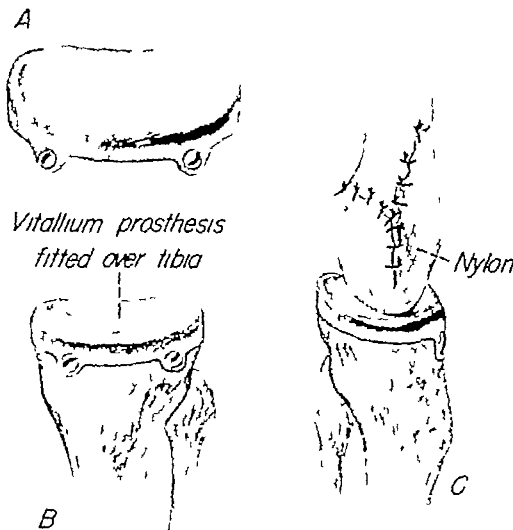


FIG 415 Arthroplasty of the knee joint (author's method) (A) Vitallium prosthesis used. The anterior and the posterior flares of the femoral condyles are removed. Also, the upper end of the tibia is resected transversely (B) The block of bone removed is sufficient to accommodate the prosthesis placed over the tibial plateau (C) The end of the femur is covered with nylon

sation of tissue reaction and favors early painless motion at the knee While in plaster the quadriceps is contracted actively on a regulated schedule from 10 to 15 times every hour this begins on the third or the fourth day After the removal of the plaster cast the limb is placed in balanced traction and active flexion and extension of the knee is started At first care is taken to avoid excessive or forceful motions in order to prevent recurrence of swelling and pain if this occurs the limb is again placed at rest until all evidence of reactive swelling has subsided At all times motion should be gentle and within the tolerance of pain as the index of pain becomes diminished motion is increased gradually Physical measures such as radiant heat and gentle massage are valuable adjuncts and add much to the patient's comfort The regimen of balanced suspension is continued for 3 weeks after which the patient is allowed up on crutches but no weight bearing is permitted until the ligaments and the muscles have tightened

As a rule at the end of 8 weeks the patient is ready to start partial weight *bearing this is achieved by a weight-bearing* caliper with a Thomas ring and an adjustable joint at the knee the apparatus protects the knee from strain and provides the patient with a sense of stability at the knee joint Full unprotected weight bearing is not permitted until there is roentgenographic evidence that the bone pattern is approaching normal and the bony trabeculae have arranged themselves along the lines of stress moreover the quadriceps muscle must have regained good power and volume

During the aforementioned period every effort possible must be made to redevelop tone and power in the muscles motorizing the knee joint in addition to increasing progressively the arcs of flexion and extension Active progressive exercises against increasing resistance on a specific routine is the best method to attain this goal

Features Constituting an Acceptable Arthroplasty Critical analysis of the end result studies of *arthroplasty of the knee* published by different surgeons such as Campbell Putti MacAusland and Hass, discloses that restitution of normal function is obtained only in the rarest cases However a serviceable range of painless motion and good stability of the joint is achieved in a relatively high percentage of cases The newly formed joint can scarcely be compared with the highly specialized mechanism of the normal joint nevertheless functional adaptation converts the simple man made articulation into a joint acceptable to both the patient and the surgeon and a joint that will stand up under daily usage for an indefinite period of time

The average arthroplasty has a range of motion of 60° to 70 generally accompanied by some crepitus beneath the patella. Excessive strain will initiate some pain and swelling When the knee is flexed and the muscles are relaxed varying degrees of instability are demonstrable With the muscles tense especially when the knee is extended the amount of instability is *negligible As a rule the gait approaches* normal and a limp is barely detectable In most cases mounting steps is performed with some difficulty

Hass classified 44 per cent of his cases as excellent and 33 per cent as good results the follow up period in this series was 5 years or more Campbell noted in his large series that during the first 2 or 3 years certain degenerative and adaptative alterations occurred in the joints and except in the rare case the ultimate degree of motion stability and functional capacity is not achieved within this period During the next 2 or 3 years there is a progressive slow increase in motion and muscular control of the joint reaching the maximum degree of function and stability from 5 to 7 years after the operation Thereafter a stationary phase ensues and no further change is noted clinically or roentgenographically

Transplantation of Tendons at the Knee for Paralyzed Quadriceps

Historical Considerations. According to Waterman, grafting and transference of tendons in traumatic cases were not uncommon procedures for several decades before Karl Nicoladoni (1880) conceived the idea of applying this same principle to paralyzed muscles He attempted to re-establish muscle power in a case of paralytic calcaneus by transferring the severed proximal ends of the tendons of the peroneus longus and brevis to the distal end of the divided tendo achillis Although the operation was a failure because the tendon anastomosis separated, the same technic was employed by Drobnick (1896) in 16 cases with satisfactory results. Following Drobnick's report, muscle transference gained popularity and for the first time in America, Goldthwait and Milliken working independently joined the lower end of the sartorius muscle to the tendon of the rectus femoris in a case of paralysis of the quadriceps muscle This principle was conceived first by Parrish in a case of paralytic valgus in 1892 he sutured the tendon of the extensor hallucis to that of the paralyzed tibialis anticus, both tendons being left intact. Lange and Krause (1898) in Europe and Painter (1902) in America successfully restored power of extension in a case of a paralyzed quadriceps muscle by transferring the tendon of an active biceps femoris muscle directly to the patella the tendon occupies a subperiosteal position on the anterior surface of the patella. This operation has gained much popularity both in America and in Europe and has been accepted as a standard procedure in the armamentarium of the orthopedic surgeon More recently some surgeons advocate transference of one of the medial hamstrings the sartorius or the semitendinosus muscle to the patella in addition to the biceps femoris this addition ensures against lateral subluxation or dislocation of the patella that results from the pull of the unopposed biceps femoris

General Considerations. The success of tendon transplants in the region of the knee, as elsewhere in the body, is governed by many factors such as the proper selection of cases, the skill of the surgeon, adherence to established principles of tendon surgery and adequate supervision of the postoperative management Much of our present-day knowledge of the physiologic and biologic aspects of tendon surgery stems from the work of Biesalski and Mayer The impetus to this phase of the development of tendon surgery was provided in a large measure by Codivilla who was the first observer to note the significance of preserving the tendon-to-tendon sheath gliding mechanism. The prime principles in tendon surgery are

1 The use of gentleness and atraumatic technic in handling tissues, particularly the tendon and its covering, this preserves the gliding mechanism and prevents peritendinous adhesions

2 The power and the efficiency of the transplanted muscle should approach the normal power of the muscle to be substituted This is of special importance in the lower extremity where one desires stability in addition to motion Failure to achieve this goal leads to instability and formation of deformities

3 Functional integrity of a muscle must be preserved All portions of a muscle work as a single unit one portion will not perform independently of or antagonistically to another

4 The line of pull of a transplanted tendon must be mechanically efficient it must effect a straight line of pull As pointed out by Mayer in cases of transference of the flexors of the knee to replace a paralyzed quadriceps, the muscles must be mobilized sufficiently to permit upward displacement of the patella when they contract If the muscles are freed insufficiently, their pull is in a dorsal direction, hence, the patella

is pulled against the femur instead of in a proximal direction

5 Every effort must be made to preserve or restore the gliding mechanism of the transferred tendon Codivilla designed a method wherein the transplanted tendon traversed the sheath of the tendon to be substituted Reconstruction of a working gliding apparatus is the chief concern of every surgeon who is effecting a tendon transplant In the region of the knee the problem is less difficult than in the hand or the arm here the usual operation is transference of the flexors of the knee to the patella the tendons traverse tunnels made through subcutaneous fat Functional adaptation converts the fat tissue surrounding the tendons into a smooth gliding system

6 The degree of tension of the transferred tendon should approach its normal physiologic state of tension This is difficult to ascertain In general tension should be of such a degree that no slack is demonstrable when the joint is in the desired position

7 In the region of the knee periosteal attachment is preferred to tendon to-tendon attachment this method ensures the best possible anchorage Technical details must be executed meticulously in effecting periosteal anchorages failure to do so has brought unsatisfactory results in many cases

8 Existing deformities must be corrected before or at the time of tendon transference It is absurd to expect a transplanted tendon to correct an existing deformity This becomes more apparent when one realizes that a normal tendon would be unable to overcome the handicap

9 The time for motion to begin must be decided by the surgeon who knows the type of anchorage performed and is able to judge when the attachment is sufficiently secure to allow mobilization of the tendon

Indications. In most instances tendon transference in the region of the knee is performed to restore extensor power in cases of paralysis of the quadriceps muscles. If the quadriceps is active and paralysis of the flexors exists no transplantation is necessary because in walking flexion of the knee is achieved by gravity when the hip of the affected limb is flexed Hyperextension or slight recurvatum at the knee favors stability, provided that the flexors of the hip and the gastrocnemius muscles possess good power In these cases the knee is locked in hyperextension at the end of each step Although the disability associated with a paralyzed quadriceps is severe most patients make adequate compensating adjustments that permit free ambulation without supporting the knee A common gait adopted is that of stabilizing the knee by rotating the limb outward so that transverse axis of the knee approaches the sagittal plane another mode of walking is throwing the leg forward taking very short steps the movement is executed rapidly so that the knee has no time to buckle under the body weight Both methods of walking are undesirable because they permit abnormal stress to act on the knee the ankle and the foot. Relaxation of the posterior structures of the knee occurs frequently and results in varying degrees of genu recurvatum the foot of the involved limb may develop pes valgus In the face of the aforementioned abnormalities transference of the flexor tendons to restore extensor power is justifiable

After the decision to transplant flexor tendons to the quadriceps has been made the type of operation is dependent upon the status of the hamstring muscles Clinical experience discloses that transference of two flexors one on each side gives the most satisfactory results the most desirable pair comprises the biceps femoris and the semitendinosus O'Donoghue utilizes this method and has reported excellent results In the event that the emitendinosus is inefficient the sartorius or the gracilis may be substituted Some workers employ only the biceps femoris this method results in satisfactory

function, but the unopposed pull of the biceps femoris is apt to subluxate the patella to the lateral side of the knee joint This occurred in 4 of the author's cases and has been reported by other workers Crego and Fischer pointed out that the most suitable candidates for biceps femoris transplant are those demonstrating good power in the muscles of the hip and the calf but the quadriceps paralysis makes walking difficult without some supporting appliance The dual transference method not only eliminates the possibility of subluxation of the patella but also provides a more powerful extensor apparatus It is generally accepted that some flexors of the knee must be left intact, the minimum being one flexor and an active gastrocnemius muscle

Transference of the sartorius and the tensor fascia femoris, although at one time a very popular procedure, is seldom employed, because the strength of the new extensor mechanism is not adequate moreover, the tensor fascia femoris contributes considerably to the lateral stability of the knee joint and therefore, if possible should not be disturbed This method is justifiable only in those cases wherein the quadriceps power is not seriously impaired

Associated Deformities. Quadriceps paralysis is associated frequently with other deformities of the knee the hip or both In the region of the knee the two common concomitant deformities are varying degrees of flexion contracture often associated with some external rotation and subluxation of the tibia and genu recurvatum Flexion deformity may be the result of unopposed action of the flexors the severity varies in degree being contingent on the degree and the duration of the muscle imbalance If the power of the biceps femoris exceeds that of the internal hamstrings the tibia is not only rotated externally and abducted on the femur but it may be subluxated posteriorly Prolonged action of active muscles may produce torsion deformities of the femur and the tibia Yount (1926) and later Forbes (1928) pointed out the role of the tensor fascia femoris in certain deformities of the lower extremities They noted that contracture of this structure was responsible for abduction contracture of the hip and external rotation abduction and flexion of the tibia on the femur, especially in cases with an inefficient or paralyzed quadriceps The biceps femoris was considered as a major contributing factor in producing the alterations of the knee joint In mild contractures these observers advocated division of the iliotibial band and the lateral intermuscular septum, and in some cases lengthening of the biceps femoris muscle Yount (1938) designed an operation employing the fascia lata and in some cases the biceps femoris to restore extensor power and relieve the deformities Through the iliotibial band he utilizes the tensor fascia femoris and a fair portion of the gluteus maximus muscle which fuses with the former muscle in the iliotibial band

As noted previously, before tendon transference is carried out all deformities of the knee the hip and the ankle must be corrected Contractures of the knee if mild in nature will respond to simple measures such as gradual stretching skin traction to the leg or wedging of a plaster-of Paris cast Severe contractures require more radical methods such as posterior capsulotomy with or without lengthening of the tendons of the hamstring muscles occasionally supracondylar osteotomy of the femur may be necessary in severe fixed flexion deformities or in torsion deformities of the femur or the tibia

On the other hand mild degrees of genu recurvatum cause no disability and in many instances are desirable because they enhance the stability of the knee in walking severe grades of recurvatum increase functional disability and must be corrected

Transplantation of Biceps Femoris and Semitendinosus Muscles (Fig 416) Three skin incisions are employed in this procedure the first over the anterior sur

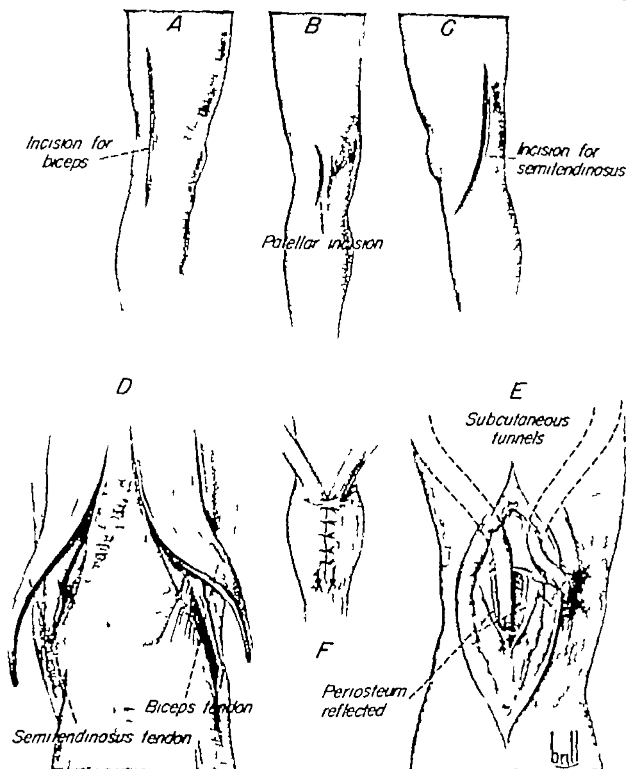


Fig 416 (A to F) Steps in transference of the tendons of the biceps femoris and the semitendinosus to the patella for paralysis of the quadriceps muscle note that 3 incisions are utilized The method of anchorage of the tendons to the patella is depicted clearly in E and F

face of the patella the second along the course of the biceps femoris, and third along the posteromedial aspect of the thigh The first skin incision is approximately 3 inches in length with a slight convexity it is placed over the anterior surface of the patella Its skin flaps are dissected on each side until the surface of the patella the

patellar tendon below and the quadriceps tendon above are visualized A vertical incision is made in the mid line of the patella, dividing the fascial layer, the quadriceps tendon and the periosteum, the incision is deepened to the bone, a transverse incision is made along the base of the patella, thereby converting the vertical incision into a T The two flaps are dissected from the anterior surface of the patella With a sharp gouge a deep vertical groove is made in the mid line of the patella, its depth should be sufficient to accommodate readily the tendons of the biceps femoris and the semitendinosus. From the upper pole of the incision two subcutaneous tunnels are formed one directed obliquely upward and medially, the other obliquely upward and laterally, the latter must be sufficiently wide to permit the transplanted biceps femoris muscle to glide freely

The second skin incision is made along the course of the biceps femoris muscle and tendon, it begins slightly below the head of the fibula and extends proximally along the posterolateral aspect of the thigh for a distance of 10 to 12 inches The common peroneal nerve is dissected free from the medial border of the biceps tendon and retracted gently laterally After the tendinous insertion of the biceps muscle is freed from all surrounding tissues it is severed from the head of the fibula At this point one must bear in mind the relationship of the fibular collateral ligament to the biceps tendon the tendon winds around the ligament in such a fashion that the ligament appears to split the tendon into a superficial and a deep portion Care must be exercised in not cutting the collateral ligament when the tendon is detached If a portion of the ligament should be cut it must be reattached to the fibula Occasionally if the length of the biceps tendon appears to be too short to reach the patella it may be necessary to remove a prolongation of the fascia lata of the thigh with the biceps tendon Dissection of the biceps tendon and muscle is carried proximally until the structure is mobilized sufficiently to permit its displacement anteriorly without tension Precautions must be taken to avoid injury to the nerve supply of the short head of the biceps muscle, the sciatic nerve and femoral vessels in the upper limits of the incision Now, the muscle and the tendon are ready for transference, the tendon is passed through the subcutaneous tunnel directed upward and outward that was formed in the first stage of the operation The course of the muscle should be slightly oblique approaching closely a vertical path, the end of the tendon should reach its new bed in the patella The lateral incision is closed in layers

The third skin incision runs parallel with the course of the medial hamstrings on the posteromedial aspect of the thigh It begins at the insertion of the inner hamstrings into the tuberosity of the tibia and continues proximally for about 10 inches. The semitendinosus is situated immediately behind the sartorius and below the gracilis it is severed at its point of insertion and mobilized as far as the upper limits of the incision It is freed sufficiently so that it can be shifted anteriorly without difficulty, the free end of the tendon is now drawn through the remaining subcutaneous tunnel and should reach the patella The medial incision is closed in the usual manner

The next stage of the operation is anchorage of the biceps femoris and semitendinosus tendons in the groove constructed previously on the anterior surface of the patella As noted previously, no slack should be present in the tendons after their fixation to the patella. The tendon of the biceps femoris is attached first. The tendon is laid in the groove and its end is fastened to the lower pole of the patella by a suture of medium sized silk which passes through the biceps tendon, the bone of the patella and the patellar tendon To ensure firm anchorage several cross stitches are passed through the patellar tendon The tendon of the semitendinosus is embedded in a similar fashion In addition the two tendons as they lie side by side in the groove are tacked to one

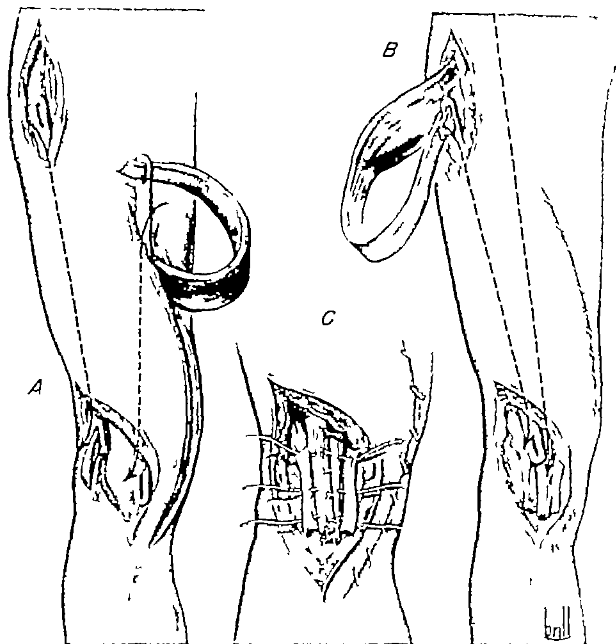


FIG 417 Transference of the tensor fascia femoris and the sartorius muscles to the patella for paralysis of the quadriceps muscle (Ober) (A) The iliotibial band is divided at its point of insertion into the head of the fibula. The tendon of the sartorius is divided at its site of insertion into the tibia. The belly of the muscle is mobilized as far as the thigh. (B) Both the tensor fascia femoris and the sartorius are transplanted to their new anatomic position. (C) Method of anchorage to the patellar tendon and patella.

another by interrupted cotton sutures Finally the edges of the periosteal fascial flaps dissected previously from the anterior surface of the patella are approximated

POSTOPERATIVE MANAGEMENT With the limb in 180 extension a plaster-of Paris cast is applied which extends from the toes to the groin This immobilization i maintained from 3 to 4 weeks then the cast is removed and active progressive exercises and physical therapy are instituted The patient must be taught to employ the transferred flexors as extensors of the knee in most instances this is accom

plished readily Radiant heat and gentle massage are valuable adjuncts in restoring normal circulation and dissipating post operative tissue reactions After removal of the cast, the extremity is protected by a posterior splint of plaster of Paris this can be taken off during the exercise periods and then reapplied Weight-bearing is allowed 2 months after the operation Now the plaster splint is replaced by a long leg brace with a lock at the knee that holds the limb in complete extension while walking When the patient has acquired strong extensor action in the transplanted muscles motion at the knee is allowed in the brace However, a posterior plaster splint should be worn at night for 3 months or longer After the patient has achieved strong extension power and the knee is stable the brace is discarded usually this is accomplished in 12 to 16 weeks

Other Combinations of Flexor Tendons Employed for Quadriceps Paralysis.

BICEPS FEMORIS AND SARTORIUS MUSCLES The author prefers this method when an inefficiency of the semitendinosus exists The procedure is identical in all details with that of the transference of the biceps femoris and the semitendinosus muscles described previously

TENSOR FASCIA FEMORIS AND SARTORIUS MUSCLES (OBER) This procedure is justifiable only when the biceps femoris and the semitendinosus are partially or completely paralyzed (Fig 417) By this method powerful extension at the knee must not be expected However the strength to stabilize the knee does not necessarily have to approach that of the normal quadriceps muscle in many instances a very small increase in strength in the extensor mechanism is sufficient to stabilize the knee and to produce marked improvement in the patient's walking On the other hand the above procedure must not be carried out unless some flexion power is left intact Complete absence of flexor power may precipitate a disabling genu recurvatum deformity The advantage of this operation is evident in the topographic anatomy of the sartorius and the tensor fascia femoris muscles Their location, in relation to the anterior structures of the thigh permits a better physiologic action on the patella than that of the hamstring muscles

A curved skin incision 8 inches in length with its convexity directed outward is made on the lateral aspect of the knee, it begins over the patellar ligament and continues proximally along the iliotibial band The insertion of the iliotibial band into the head of the fibula is identified and freed from the surrounding structures, a flap of fascia lata ¼ inch wide is severed from the fibula. Next a skin incision 3 inches in length is made on the lateral aspect of the thigh over the lower portion of the tensor fascia femoris A subcutaneous tunnel is bored between the two skin incisions, and the loose flap of fascia is drawn out of the upper opening The belly of the tensor fascia femoris is mobilized by freeing it from all adjacent tissues By reflecting medially the skin edge of the lower incision the patella the patellar tendon and the quadriceps tendon are brought into view a vertical incision is made in the quadriceps tendon and its fascial covering, the aponeurosis over the patella and the patellar tendon, the edges of the incision are dissected to each side for ½ inch Next, the sartorius muscle is exposed The skin incision begins at the tibial tubercle and curves gently upward on the medial aspect of the thigh it terminates on the anteromedial aspect of the thigh at the juncture of the middle and the upper thirds The lower margins of the skin incision are dissected on each side to expose the patella and the patellar tendon on the lateral aspect and the sartorius muscle on the medial aspect The tendon of the sartorius is identified and divided at its point of insertion into the tibia It lies in front of the tendons of the semitendinosus and the gracilis muscles. Next the tendon and its muscle belly are mobilized as far as

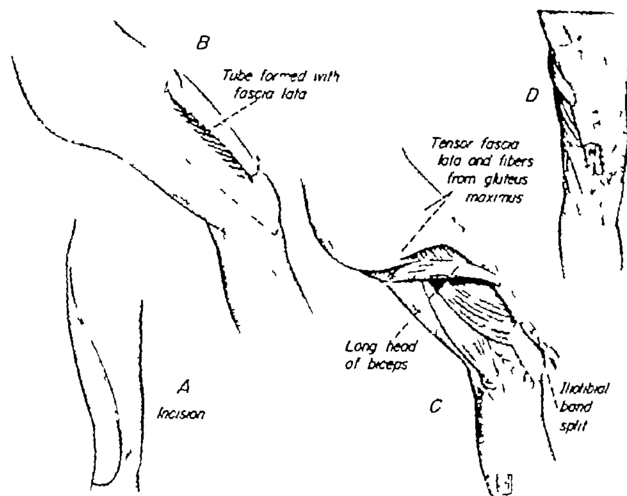


FIG 418 Transference of the tensor fascia femoris and the biceps femoris muscles to the patella This method is employed in cases with quadriceps paralysis exhibiting a flexion and an external rotation deformity of the tibia on the femur resulting from contracture of the iliotibial band (Yount) (A) Incision. (B) Formation of fascial tube (C) Depicts sites of entrance of the (1) iliotibial band into which are inserted the tensor fascia femoris and a portion of the gluteus maximus and (2) the long head of the biceps femoris muscle (D) Method of attachment of the transplants to the patella and the patellar tendon.

the middle of the thigh in this step precautions must be taken not to injure the saphenous nerve which occupies a position in relation to the posterior border of the sartorius muscle An Y suture of silk is passed through the end of each transplant By means of a fascia carrier the iliotibial band is passed beneath the fascia lata so that its distal end emerges from the lo wound over the quadriceps tendon, wise the sartorius muscle and tend passed through a perforation made intermuscular septum between the sart and the quadriceps he end o

tendon appears in the lower wound over the quadriceps tendon The free ends of the transplants are now ready for anchorage with the knee extended and the thigh flexed 45 the tendon of the sartorius is fastened to the patellar tendon by silk sutures the distal end of the iliotibial band is uper imposed ove e sartorius and it also is to t endon Both structures other by interrupted lges of the reflected a are approximated

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MUSCLES (YOUNT) (Fig 418) This operation was designed by Yount primarily for those cases wherein the quadriceps is paralyzed, both the inner and the outer hamstring muscles are acting and, because of contracture of the iliotibial band, flexion deformity of the knee and external rotation of the tibia on the femur ensue By this operation the aforementioned deformities of the knee are remedied, and extensor power is restored to the thigh. The tensor fascia femoris muscle and the posterior portion of the gluteus maximus which inserts in the fascia lata, together with the biceps femoris muscles, are utilized to attain the desired extensor power

The skin incision begins just below the greater trochanter and continues distally toward the middle of the dorsal surface of the thigh to the patella it runs across the patella and ends on the lateral aspect of the outer tuberosity of the tibia Reflection of the skin and the subcutaneous tissue to each side by blunt dissection exposes the fascia lata from the middle of the thigh to its inferior margin of the lateral surface proximally the reflection is continued until the insertion of the gluteus maximus muscle into the fascia lata is adequately exposed By retracting the lower skin flap laterally the tendon of the biceps is visualized next the tendon above the head of the fibula is mobilized and ⅔ of its thickness is stripped free from its point of insertion in the head of the fibula. Dissection of the tendon continues proximally until the muscle fibers of the short head come into view dissection of the long head continues upward leaving the short head behind The long head is mobilized sufficiently to allow its displacement to the new position with ease Separation of the long and the short heads is facilitated by the presence of a distinct line of cleavage between the two muscle bellies The short head left in situ ensures against the development of genu recurvatum. Next the iliotibial band is made ready for transference. A narrow strip approximately ½ inch wide is freed by subperiosteal dissection from the tuberosity of the tibia it extends upward across the knee joint to that portion of the iliotibial band which is well defined Beginning 2 inches proximal to the knee joint, the strip of fascia lata including the iliotibial band is widened gradually this continues as far as the upper third of the thigh It gains considerably in width as it nears the insertion of the gluteus maximus muscle here it is stripped free up to the point where the fibers of the gluteus maximus insert into it On the medial side the fascia is stripped up so as to include the tensor fascia femoris muscle

A tube of fascia lata which will enclose the transplants is constructed and so placed that it will maintain the new extensors of the knee in a position approaching that of the quadriceps The tube is made from the inner lip of the cut fascia lata by folding it upon itself toward the mesial aspect of the limb It is so placed in the upper part of the thigh that it occupies a lateral position from which it continues gradually and obliquely toward the middle of the thigh as it approaches a point 3 inches proximal to the base of the patella The free end of the iliotibial band enters the tube at the top, the biceps tendon enters it 2 inches from the top through a separate aperture After the biceps emerges from the distal end of the fascial tube it is fastened to the iliotibial because its length is not sufficient to reach the patella. After the quadriceps tendon is divided in the mid line 1½ inches above the patella both transplants are sutured to it The terminal segment of the fascial transplant is divided into two strips and each is passed through holes drilled in the patella The wound is closed in the usual manner and the limb is immobilized in a plaster-of Paris cast extending from the toes to the groin If some flexion contracture of the knee is still present at the end of the operation only moderate force should be used to correct it, complete correction may

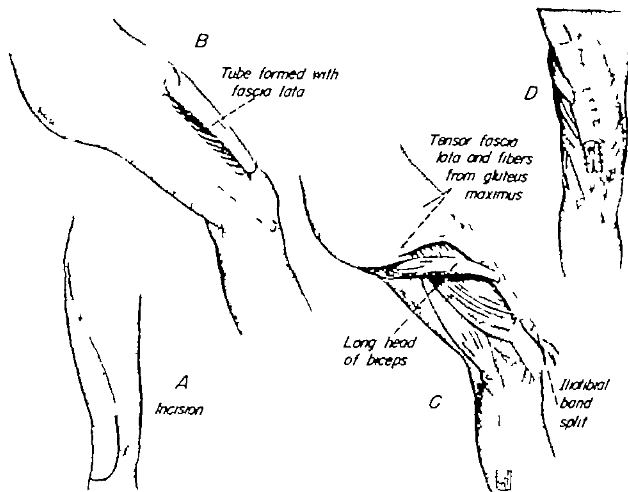


FIG 418 Transference of the tensor fascia femoris and the biceps femoris muscles to the patella. This method is employed in cases with quadriceps paralysis exhibiting a flexion and an external rotation deformity of the tibia on the femur resulting from contracture of the iliotibial band (Yount) (A) Incision (B) Formation of fascial tube. (C) Depicts sites of entrance of the (1) iliotibial band into which are inserted the tensor fascia femoris and a portion of the gluteus maximus and (2) the long head of the biceps femoris muscle. (D) Method of attachment of the transplants to the patella and the patellar tendon.

the middle of the thigh in this step precautions must be taken not to injure the saphenous nerve which occupies a position in relation to the posterior border of the sartorius muscle An X suture of silk is passed through the end of each transplant By means of a fascia carrier the iliotibial band is passed beneath the fascia lata so that its distal end emerges from the lower wound over the quadriceps tendon likewise the sartorius muscle and tendon are passed through a perforation made in the intermuscular septum between the sartorius and the quadriceps muscles the end of the tendon appears in the lower wound over the quadriceps tendon The free ends of the transplants are now ready for anchorage with the knee extended and the thigh flexed 45 the tendon of the sartorius is fastened to the patellar tendon by silk sutures the distal end of the iliotibial band is superimposed over the sartorius and it also is fixed to the patellar tendon Both structures are tacked to one another by interrupted sutures Finally the edges of the reflected aponeurosis of the patella are approximated over the transplants

TENSOR FASCIA FEMORIS AND BICEPS

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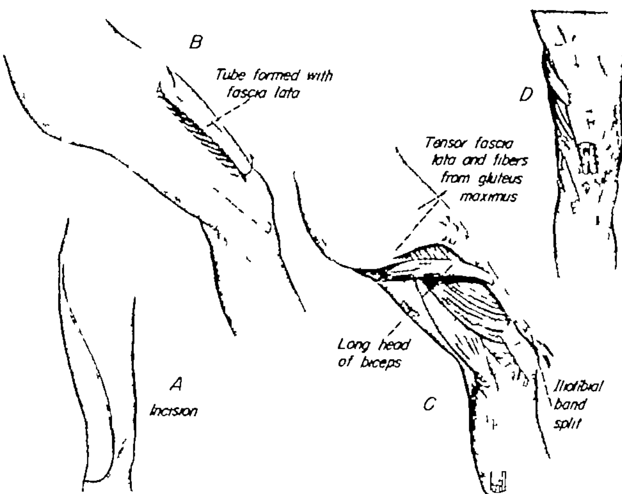


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not be attainable at this time It may be necessary to defer final correction of the deformity until after complete healing has been achieved which is approximately 4 weeks this is accomplished by means of a wedged cast.

Transplantation of the Biceps Femoris Muscle Powerful extensor power is not essential to increase the stability of a knee joint with quadriceps palsy and to improve walking In cases wherein the biceps is acting and insufficient flexor structures preclude transplantation of one of the medial hamstrings in combination with the biceps the biceps alone may be converted into an extensor of the knee. The resulting enhancement in walking and in the stability of joint justifies the procedure The technic is similar to the method described when the biceps is transplanted in combination with the semitendinosus

Drainage for Sepsis of the Knee Joint

As stated previously in the section dealing with pyogenic arthritis of the knee joint, the use of chemotherapy and antibiotics has reduced considerably the number of cases of pyarthrosis which require surgical drainage However some infections particularly some strains of staphylococci are resistant to the aforementioned agents as well as to other conservative methods In such instances drainage must be performed On the other hand since the advent of antibiotic agents the author has not encountered a single case of acute gonorrheal arthritis of the knee joint which did not respond to the conservative measures comprising rest hot packs aspiration of pus and instillation of antibiotics this has been the experience of other surgeons *If drainage is decided upon* the anterior routes are preferred to the posterior ones because the latter may be complicated by extension of the infection up and down along the fascial planes of the limb Distention of the posterior compartments or a localized abscess in these regions makes it mandatory that a posterior approach be employed

In general, the knee joint cavity is divided roughly into anterior and *posterior compartments* On the medial side the line of separation consists of the medial intermuscular septum and the tibial collateral ligament and on the lateral side the dividing structures are the lateral intermuscular septum and the fibular collateral ligament. It becomes apparent that operative approaches to the anterior or the posterior compartments are devised in relation to the aforementioned septa Knowledge of the anatomy of some of the bursae in the popliteal region facilitates approaches to the popliteal space It was noted in Chapter 3, which deals with normal anatomy of the knee joint that large bursae in this region frequently communicate directly with the joint cavity they are the bursae located between the medial head of the gastrocnemius and the semimembranosus muscles *This anatomic feature is of* clinical significance because the posterior region of the joint cavity may be drained adequately by opening the posterior walls of the bursae Another natural perforation in the joint capsule is made by the popliteus tendon an extension of the synovial lining of the joint projects on the anterior surface of the popliteus tendon and muscle In the light of these anatomic characteristics incisions on the posteromedial aspect of the tibia allow access to the anterior surface of the popliteus muscle and if continued proximally following the popliteus tendon the posterolateral region of the knee is entered

The author no longer employs continuous open drainage of the knee joint. If it becomes necessary to drain the joint cavity by one of the incisions described below after *thorough irrigation of the joint cavity* the synovial capsule is closed and the overlying tissue layers are approximated loosely Occasionally they are left open with a drain placed in the wound as far as the closed synovial layer By so doing synovial fluid is not removed continuously from the joint

As noted previously, the synovial fluid in its normal state has powerful antiseptic powers that should be utilized to combat the existing infection

For academic reasons and for the sake of completeness the following technics designed for drainage of the knee joint are included as described by their originators

Anterior (Parapatellar) Incisions. With the patient in the supine position and the knee flexed 20° to 30° two vertical skin incisions from 3 to 4 inches in length, are made on both sides of the knee they extend from the upper limits of the suprapatellar pouch to the upper borders of the tuberosities of the tibia The incisions are deepened through the superficial fascia, the deep fascia, the aponeuroses of the vasti and the synovialis. Occasionally, it may be necessary to fasten the edges of the synovialis to the skin margins by interrupted sutures of fine plain catgut in order to prevent closure of the incisions and spread of the infection along tissue planes. Drains never should be introduced into the joint but are inserted down to the level of the joint

Posteromedial Approach (Klein) (Fig 419) This approach is centered over the posteromedial aspect of the knee joint and follows natural planes of cleavage it re

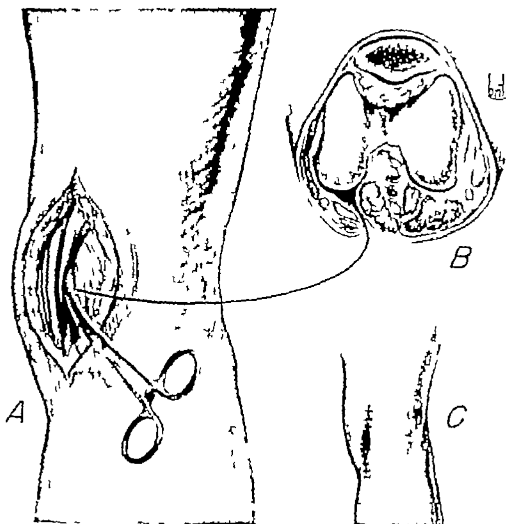


Fig 419 Technic of draining the knee joint through a posteromedial approach (Klein) (A) Instrument placed between the semitendinosus and the inner head of the gastrocnemius muscles indicates the point of entrance into the joint cavity (B) Depicts the same point of entrance in a cross section through the knee joint. (C) The synovialis is stitched to the skin to ensure drainage

quires minimal amount of mobilization of vessels and nerves Moreover, with the patient in the supine position, free dependent drainage of the inner and the posterior compartments is achieved readily

The patient is placed in the prone position with the affected limb supported on sandbags so that it lies at a higher level than the opposite limb The skin incision is approximately 4 inches in length and is placed over the inner side of the posterior aspect of the joint, the center of the incision is over the joint line the incision runs parallel with the semitendinosus muscle on its outer side After the superficial fascia is incised the incision is deepened by blunt dissection developing the interval between the semitendinosus and the inner head of the gastrocnemius muscles Retraction of the muscle brings into view the deep fascia and the fat overlying the internal condyle of the femur immediately beneath these structures lies the capsule of the joint Fascia capsule and synovialis are incised in the same line as the skin incision thereby exposing the interior of the posteromedial region of the joint cavity The upper limits of the incision are bounded medially and superiorly by the semitendinosus and the semimembranosus muscles while its lower limit projects to the superior border of the popliteus muscle To ensure adequate drainage the synovial membrane and capsule are stitched to the subcutaneous fascia A drain is inserted in the cavity as far as the level of but not in the joint cavity The skin edges around the aperture are approximated with interrupted sutures.

Posteromedial and Posterolateral Approaches (Henderson) (Fig 401) These approaches described on page 661 provide adequate drainage of the posteromedial and posterolateral compartments of the knee joint When used in combination or if Klein s incision is employed with Henderson s posterolateral approach through and through drainage of the joint is obtained

Posterior mid line incisions as advocated by Osgood, Brackett and Putti are rarely used to drain the posterior compartments of the knee joint.

Postoperative Management. It is essential to place the affected limb at complete rest after the surgical procedure and during the acute phase of a suppurative arthritis This is achieved best by simple adhesive traction to the lower leg In addition the method overcomes muscle spasm tends to keep the articular surfaces of the femur and the tibia separated and prevents contractures. At this time continuous applications of voluminous hot packs add much to the comfort of the patient and also provide some immobilization of the part After the acute inflammatory process has subsided motion, both passive and active is started at the knee. All movements should be within the patient's tolerance of pain forceful motion or excessive early motion may be responsible for swelling pain and muscle spasm. The first active motion should be contraction of the quadriceps muscle pulling the patella upward later movement at the joint is begun Restriction of function is enhanced by placing the limb in balanced suspension Weight bearing should be prohibited until all evidence of inflammation has subsided and the patient has developed good extensor power in the quadriceps muscle At this time weight bearing should be protected by the use of crutches braces and cages should not be employed except as a last resort. In order to prevent flexion deformities at the knee a posterior splint is applied during the night it may be necessary to wear the splint for many months Underwater exercise is a useful adjunct in increasing the arc of motion and developing muscle tone It is most essential to impress on the patient that progress is naturally slow and that whole-hearted co-operation is essential in order to restore joint function.

As noted previously when the author employs the incisions described the synovial capsule is closed and in addition to the aforementioned postoperative measures in

tensive antibiotic therapy is instituted, both locally and systemically The plan carried out is similar to that described in the section dealing with infected wounds of the knee joint

RESECTION OF UPPER END OF FIBULA

It now is established definitely that as much as three fourths of the proximal portion of the fibula may be sacrificed without any deleterious effects on function of the lower limb On the other hand, the distal one fourth of the fibula comprises the outer component of the ankle mortise and contributes in a large measure to the stability of the ankle joint Resection of the upper end of the fibula is justifiable in instances of chronic osteomyelitis of this portion of the bone, the procedure ensures a certain cure Neoplastic lesions implicating this region are treated by resection of the bone chief among these are giant-cell tumors and chondrosarcomas (Fig 420) If the latter tumor is limited to the fibula, resection of the bone is the treatment of choice On occasions the upper portion of the fibula may be transplanted to replace bone defects the size and the configuration of the head of the fibula lend themselves to replacement for defects of the upper end of the humerus and for the distal end of the fibula The author on three occasions, has utilized the upper end of the fibula to replace a defect in the upper proximal end of the humerus in all instances the head of the humerus together with approximately one third of the shaft were resected because they were the seat of a giant-cell tumor In another instance it was used to stabilize the wrist in a case of congenital absence of the distal one third of the radius

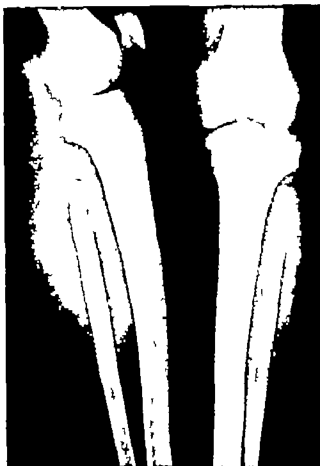


Fig 420 Resection of the upper end of the fibula. The tip of the head of the fibula was left behind in order to preserve the attachment of the fibular collateral ligament. The lesion necessitating removal of the segment of bone was an osteoid osteoma in the head of the fibula

Operative Technic (Henry) (Fig 421) The exposure designed by Henry facilitates resection of the proximal portion of the fibula the pertinent structures vulnerable in the operation are the common peroneal nerve and its 3 terminal branches The parent trunk lies directly on the neck of the fibula in this position it gives off the recurrent tibial the anterior tibial (deep branch) and the musculocutaneous branch (superficial branch) The musculocutaneous nerve continues distally directly on the shaft of the fibula between the anterior and the posterior fibers of origin of the peroneus longus It becomes apparent that complete mobilization of the aforementioned nerves is essential in order to protect them from injury

With the patient on the sound side and the knee of the affected limb flexed, a skin incision begins just behind the head of the fibula and continues vertically downward over the proximal two thirds of the shaft of

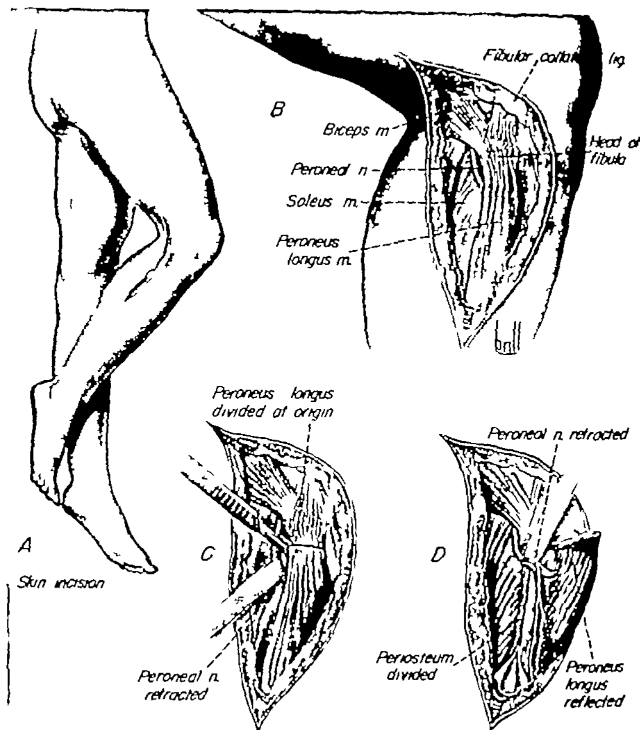


FIG 421 (A and B) Exposure of the upper end of the fibula (Henry) (C and D) That portion of the peroneus longus overlying the nerve is severed this step mobilizes the nerve sufficiently to allow its displacement anteriorly over the head of the fibula

the fibula the proximal end of the incision is extended upward for 4 to 5 inches along the tendon of the biceps muscle The superficial fascia is divided in the line of the skin incision the deep fascia is first split along the medial border of the biceps tendon and this line of division is extended vertically downward to the lower pole of the wound In the proximal part of the wound the common peroneal nerve is identified as it

emerges from under the inner border of the biceps tendon The nerve is mobilized sufficiently to allow its displacement across the tendon and the head of the fibula. The groove normally occupied by the nerve leads to the plane of cleavage between the soleus posteriorly and the peroneal muscles anteriorly In the next step, the nerve is displaced downward and with the scalpel blade directed upward, that portion of the peroneus longus overlapping the nerve is severed This step mobilizes still further the main nerve trunk so that it can be displaced a considerable distance from the neck and the head of the fibula. Dissection to the shaft of the bone is carried out through the plane of cleavage between the sulcus and the peroneal muscles the periosteum is divided, and the muscles are detached subperiosteally Care must be executed when the muscles are stripped from the shaft one is apt to injure the deep branches of the common peroneal nerve which lies on the deep surface of the peroneal muscles in the upper portion of the wound these same branches lie in close proximity to the neck of the fibula Finally the shaft of the bone is cut at the desired level with a Gigli saw and the head is freed by dividing all soft tissue attachments close to the bone. In order to provide an anchorage for the biceps tendon it may be fastened to the fascia lata and the capsule of the proximal tibulofibular joint

Amputations

General Considerations. The aim of an amputation below through or above the knee joint, should be to provide the patient with a stump which can activate a serviceable prosthesis without discomfort In order to achieve this goal the surgeon must possess adequate knowledge of the surgical anatomy of the region chosen as the site of amputation and he should be acquainted with the mechanics of the prosthesis to be worn. Much information has been made available to us over the period of many years relative to (1) the best level for an amputation, (2) what constitutes the best tissue covering for a stump, (3) the pitfalls that must be avoided in selecting the amputation site, and (4) the type of stump to be constructed The concentrated effort made during and after World War II in the numerous amputation centers established in this country and abroad to study the problems of the amputee in regard to his rapid rehabilitation has added much valuable data to our stock of knowledge on the subject of amputations The author s experience in caring for hundreds of fresh casualties, many of which required severance of one or more members and his experience in the management of amputees after the war in one of the amputation centers leads him to believe that when possible an amputation should be performed by a surgeon of sufficient skill and experience to do a definitive primary operation In this way the patient is spared numerous secondary operative procedures the period of hospitalization is reduced, and rehabilitation is expedited It is granted that in times of conflict the aforementioned idealistic requisite is impossible to attain however in civilian life, if no contraindications exist, a patient can be given this service and any other course should be condemned

One must not lose sight of the fact that the surgeon's responsibility does not terminate with severance of an individual's limb and management of the immediate postoperative period It is the moral obligation of the operator to prepare the stump for an artificial limb to prescribe the best prosthesis for the stump that he constructed and finally to guide the patient through a period of training so that he attains maximum function and achieves adequate mental and emotional readjustment to his physical handicap only then is the amputation surgeon's work completed

It is not within the scope of this section

to discuss in detail the many problems of amputation surgery This information may be obtained in the numerous excellent works that have been published within the past decade on this subject Slocum s *Atlas of Amputations* is a comprehensive study that provides valuable information However, it is permissible at this time to enumerate the generally accepted indications for severance of a limb

Indications. A limb that has no functional value should be deleted This is especially true if severance of a useless limb will make it possible to construct a stump which can wear a prosthesis with comfort and enhance the over all efficiency of the individual A functionless extremity may be the product of violent trauma, severe infections or it may be a congenital deformity

Eradication of an extremity is justifiable in the face of an acute fulminating infection which is jeopardizing the patient s life Since the advent of chemotherapy and antibiotic agents the aforementioned indication is encountered less frequently than prior to the period of their availability Nevertheless occasionally rapidly spreading infections of an extremity are confronted which fail to respond to the conventional therapeutic and surgical measures in such instances amputation of the limb is a life saving procedure Gas gangrene is the most common offender in this category Also the author has encountered 3 cases of diffuse fulminating tuberculosis—2 of the elbow and 1 of the knee joint—which were not amenable to control severance of the extremities became mandatory in order to save the patients lives Chronic osteomyelitis which has existed over many years and has failed to respond to the measures employed may have a deleterious effect on the patient s general physical status Constant absorption of toxins from the affected limb may induce severe liver and renal damage As a rule such limbs in addition to supplying continuously harmful toxins to the body are useless organs beyond the hope of functional restoration It becomes apparent that in the face of these circumstances amputation is warranted In adults control of tuberculosis of the limbs with open sinuses and mixed infections by the usual measures may be impossible to attain radical surgery in these cases may be so extensive that a useless limb is the end product with no assurance that the pathologic processes are eradicated Tuberculosis of the bones of the foot and the ankle is notorious for its resistance to the usual therapeutic measures not infrequently the devitalized tissues are invaded by pyogenic organisms producing greater sepsis and draining sinuses In such cases, amputation of the foot at a level to provide a good stump which can wear a serviceable prosthesis is not only a judicious measure but also a humane one

Neoplastic lesions implicating an extremity is a common etiologic factor responsible for severance of a limb As pointed out in the chapter dealing with bone tumors in the region of the knee joint primary malignant lesions in a limb justify deletion of the extremity when there is hope that metastasis may be prevented In the face of metastatic lesions elsewhere in the body amputation serves no purpose unless there are other circumstances to warrant the procedure A limb may be rendered totally useless by metastatic involvement moreover such an extremity may be the source of great discomfort amputation in such cases is employed as a palliative measure

As pointed out by Slocum at times an extremity is so distorted as the result of trauma or of congenital origin that it is not acceptable to the patient the rejection may be so profound that the presence of the limb may place the patient s mental equilibrium in jeopardy In such instances removal of the part restores the patient s mental status to normalcy

Preferable Sites of Amputation and Other Pertinent Considerations. If possible severance of a limb through the lower one third of the leg should be avoided In

this region the circulation is poor, and the soft tissues do not lend themselves to the construction of a serviceable stump Because of the circulatory deficiency, the stump is cold, cyanotic and frequently exhibits ulcerations of its soft tissue covering Moreover, the resulting long stump is a poor mechanical organ to motorize a prosthesis, the repeated trauma inflicted to the distal end of the stump during walking results frequently in the formation of painful bursae and ulcerations of the skin Its length interferes with a smoothly functioning ankle mechanism, therefore, a prosthesis must be made which is bulky about the ankle joint, this feature is objectionable to the patients, especially women

Clinical experience reveals that preservation of the knee joint adds materially to the efficiency and the comfort of the patient when the stump is made to conform to specific requirements which permit wearing a comfortable and serviceable prosthesis The ideal stump for below the knee amputations in the average adult is 7 inches in length measured from the superior anteromedial border of the tibial plateau to the end of the bone. This is not a weight bearing stump the weight is borne on the expanded tuberosities of the tibia. Whereas earlier amputation surgeons attempted to provide the end of a stump with a cushion of muscle tissue and skin it is now definitely established that such padding is of no functional value and even undesirable Bulbous soft tissue masses at the end of a stump increase the difficulties of fitting an artificial limb and also are prone to develop circulatory disorders resulting in edema local infection and ulceration of the tissues Instead the stump should be symmetrical tapering gently to a rounded end No bony prominence should be present either at the end or the sides of the stump the sharp anterior crest of the tibia should be shaved off to give the surface a rounded configuration The scar should be located slightly posterior and approximately 2 to 4 cm. proximal to the posterior margin of the end of the tibia, in this position it is spared undue pressure made by the back of the socket. Every effort should be made to provide the end of the stump with a covering of normal skin which is freely movable over the end of the tibia and the scar should not be adherent to the adjacent bone

Although a stump 7 inches long is considered as the most efficient lever arm in below the knee amputations occasions arise wherein it is impossible to construct such a stump Nevertheless, every effort possible should be made to preserve the knee joint a lower leg stump of 1½ inches can be fitted with a prosthesis which allows free normal action at the knee joint, a feature which permits greater control and efficiency of the artificial limb than is possible with an artificial knee joint Up to 7 inches the efficiency of the lever arm increases progressively with its increase in length.

Stumps too short to activate a prosthesis, or when flexion deformities exist which defy correction may be adapted to a bent knee prosthesis (kneeling leg') or must be reamputated above the level of the knee joint Bent knee amputations may be fitted with a prosthesis similar in mechanism to that employed for end bearing stumps above the knee joint From a functional viewpoint the bent knee amputation provides a very serviceable stump with a broad weight bearing surface It is an excellent amputation in laborers who are required to stand for long periods of time rarely does it show evidence of circulatory disorders

Some workers have recorded excellent results in amputations through the knee joint Nevertheless it is generally accepted that the unequal and bulbous condyles of the femur do not form a good weight bearing stump The overlying skin is subjected to undue pressure and friction resulting in frequent breakdowns In addition the unshapely configuration of the end of the stump makes it exceedingly difficult to fit a comfortable prosthesis the artificial

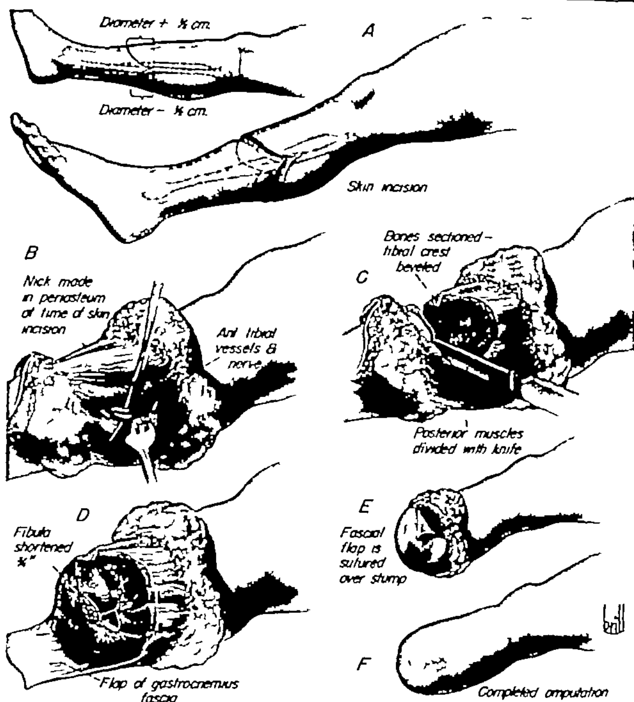


FIG 422 (A to F) Steps in amputation through the middle third of the leg (Carnes)

limb is unsightly because it cannot be shaped to match the opposite limb In children it is a justifiable procedure if the knee joint cannot be left intact Since the lower epiphysis is responsible for approximately 70 per cent of the length of the femur it becomes apparent that this important growth center is preserved in patients who have not as yet achieved complete skeletal development

There is considerable controversy relative to the disposition of the fibula in below the knee amputations. Some workers are convinced that the fibula is of no functional value in activating a prosthesis and that is the source of pain resulting from con

stant irritation of the tissues between the tibia and the fibula and finally it increases the difficulties of fitting a prosthesis These observers recommend either total excision of the fibula in all amputations through the upper one third of the leg or, if allowed to remain, a synostosis should be created between the two bones. Other surgeons, including the author are in total disagreement with the aforementioned view As pointed out by Slocum the presence of the fibula is a distinct functional advantage, its triangular shape prevents the prosthesis from rotating, thus increasing the control of the stump Also, a certain "spring action" between the tibia and the fibula which acts as a shock absorber protects the stump from undue pressure from an artificial limb To facilitate fitting of a prosthesis the fibula should be sectioned from 1 to 2 inches proximal to the distal end of the tibia In cases wherein the fibula is responsible for pain and disability resulting from excessive motion between it and the tibia or sensitive areas in overlying skin, the fibula should be resected Its removal is also advantageous in all short below the knee amputations this facilitates fitting of a comfortable prosthesis

Technics of Amputations Through the Middle Third of the Leg Numerous operations have been conceived for amputations at this level the technics described in this section have proved to give satisfactory stumps capable of activating a prosthesis with efficiency In all procedures each step should be worked out carefully before it is executed only in this manner can pitfalls be avoided and a useful stump obtained The author prefers Carnes' amputation to all others each step is performed under direct vision and if all details are observed meticulously an excellent stump is attained

Amputation of Carnes (Fig 422) The pertinent features of this operation are the following (1) The skin flaps are of unequal length, the anterior being slightly longer than the posterior (2) After the skin flaps are cut each subsequent step proceeds from the anterior to the posterior aspects of the leg (3) Each step is performed under direct vision

The length of the skin flaps is determined in the following manner the desired bone level is chosen, and the diameter of the leg at this level is measured this step determines the surface area of the skin necessary to cover the end of the stump The anterior flap is equal to the radius of the leg at the predetermined bone level plus 0 5 cm whereas the posterior flap measures the radius minus 0 5 cm hence the anterior flap is 1 cm longer than the posterior A small incision in the skin below the bone level designates the length of each flap

The skin incision for the anterior flap begins at the mid point of the medial surface of the leg at the intended bone level it curves downward as far as the marker previously placed on the skin then continues upward on the lateral aspect of the leg to a point corresponding to its medial level of origin In order to establish a fixed reference point for future measurements the incision as it sweeps across the crest of the tibia is carried through the periosteum to the bone The shorter posterior flap has its convexity directed downward and passes through the skin marker on the posterior surface of the leg Next, both incisions are deepened to the fascia investing the muscles of the leg and the skin flaps are reflected upward by sharp dissection as far as the intended bone level In dissecting the posterior flap from the fascia the sural veins and nerves are encountered the nerves are pulled down and severed and the vein is cut and ligated Inasmuch as the skin flap retracts, it is of no value in estimating the level of the saw cut through the tibia this is determined by measuring off on the bone from the incision made previously in the periosteum the original length of the flap at this level a small saw cut is made in the periosteum and the bone on the anterior surface of the tibia

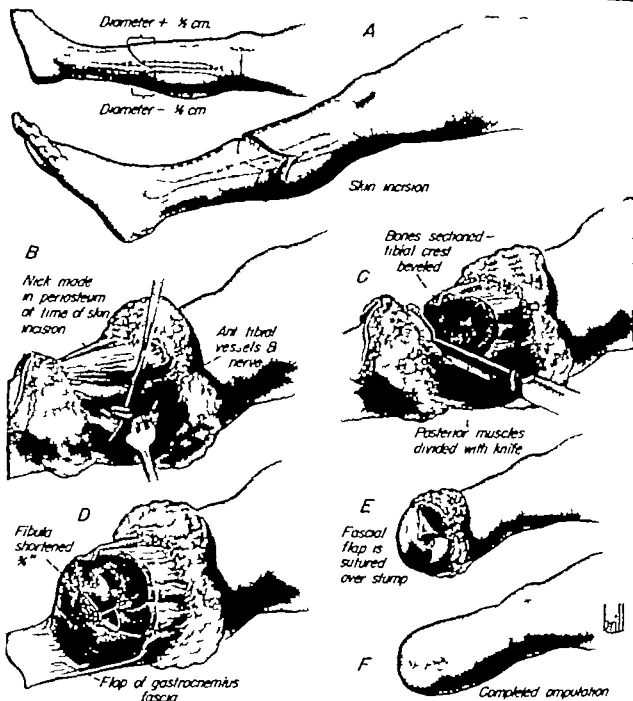


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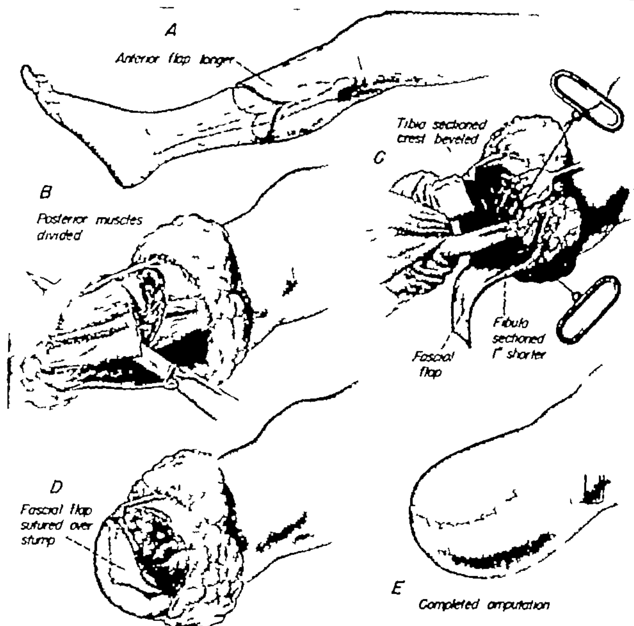


FIG 423 (A to E) Steps in tendoplastic amputation (Kirk)

Along the lateral surface of the tibia lies a natural plane of cleavage into this interval a curved hemostat is placed it is passed along the interosseous membrane onto the anterior surface of the fibula emerging anterior to the peroneus brevis muscle In the interval between the peroneus brevis and the extensor digitorum longus the superficial peroneal nerve is identified drawn downward and divided All muscles in the anterior compartment are sectioned 1/4 inch distal to the saw level upon retraction the proximal ends of the muscles will lie flush with the bone level In dividing the muscles care is taken to avoid injury to the anterior tibial vessels and nerves these are identified and isolated the vessels are doubly ligated and sectioned the nerves are drawn downward and divided In the next step the crest of the tibia is beveled this is achieved by placing the saw 3/4 inch above the bone level and carrying it obliquely downward so that it crosses the bone level 3/16 inch anterior to the marrow cavity By transverse saw cuts the tibia and the fibula are divided at the same level both bones are grasped

below the saw line by bone holding forceps and displaced downward and forward, this maneuver brings into view the posterior muscles of the calf

Division of the posterior muscles is performed by a large amputation knife, beginning ¼ inch distal to the bone level and passing obliquely backward and slightly upward until the aponeurosis of the gastrocnemius muscle is encountered Then the knife is directed downward parallel with the deep surface of this structure until a fascial flap is attained sufficient in length to cover the end of the stump, then the aponeurosis is sectioned transversely As the posterior muscles are divided the posterior tibial vessels are identified, isolated, doubly ligated and sectioned, the posterior tibial nerve is drawn downward and severed In the final step the cut end of the fibula is exposed subperiosteally for a distance of 1¼ inches proximal to the cut end of the tibia, at this level the fibula is divided transversely with a Gigli saw, the remaining periosteal sleeve is dissected free under direct vision so that bleeding from this source can be controlled readily Both bone ends are made smooth with a bone file The end of the stump closure of the wound is achieved by bringing forward the fascia of the gastrocnemius muscle and fastening it to the anterior muscle fascia and periosteum by interrupted sutures. If the muscle mass is bulky it may be trimmed by taking out a medial or lateral wedge before the fascia is sutured The skin flaps are brought together and fixed by interrupted skin sutures After adequate dry dressings are applied over the end of the stump gentle compression is made with a 3 inch elastic bandage extending from the end of the stump to above the knee Further protection and immobilization to the part are provided by a posterior plaster splint reaching from the mid thigh to the anterior margin of the stump.

Tendoplastic Amputation of Kirk (Fig. 423) The essential feature of this procedure is the formation of a long anterior and a short posterior flap, the ratio being 3 to 2 In addition, the posterior flap comprises a thinned layer of muscle, tendon and fascial structures derived from the posterior aspect of the leg The length of stump is measured from the point of insertion of the inner hamstring muscles

With the patient in the supine position, the anterior skin incision starts at the mid point on the medial aspect of the leg just proximal to the intended bone level It continues distally and laterally crossing the anterior surface of the leg then proceeds upward on the lateral aspect to a point corresponding to the one of origin on the medial side The posterior flap is cut in a similar fashion. By sharp dissection the anterior flap is reflected slightly above the saw line, while the posterior flap is dissected proximally for ½ inch The skin distal to the posterior incision is freed for 2 to 3 inches, exposing the aponeurosis of the gastrocnemius muscle. By a transverse cut the muscles in the anterior compartment of the leg are sectioned ¼ inch distal to the bone level using a long amputation knife, the posterior calf muscles are transfixed behind the tibia and the fibula at the level of the saw line. The knife is drawn downward and backward through the posterior muscles this maneuver creates a tongue-shaped flap comprising muscles, tendon and fascia its length should be sufficient to cover the end of the stump One fourth inch proximal to the bone level the periosteum is sectioned circumferentially, except over the crest of the tibia where the line of division continues proximally for ½ inch this allows beveling of the tibia. After the fibula is stripped of muscle attachments for a distance of 1 inch and the tibial crest is beveled beginning at a point ½ inch above the saw line the tibia is sectioned at right angles to the long axis of the leg and the fibula is divided by a Gigli saw 1 inch proximal to the end of the tibia All bone surfaces and margins are made smooth with a bone file. The pos-

terior flap is now ready for final trimming Sufficient muscle tissue is cut away from its anterior surface to form a thin flap measuring in thickness ¼ inch at the base and ⅛ inch at the apex. The length of the flap should be sufficient to reach the muscle fascia and periosteum on the anterior aspect of the leg all excess tissue is cut away The anterior and the posterior tibial and the peroneal arteries are identified and doubly ligated other large vessels are treated in a similar manner The nerves of the leg are drawn downward cut and permitted to retract upward Finally the posterior flap is *approximated and sutured by interrupted* sutures to the anterior muscle fascia and periosteum on the medial aspect of the tibia the skin flaps are brought together and fixed by skin sutures.

Dry sterile gauze pads are placed over the end of the stump and uniform compression is made by a 3 inch elastic bandage enclosing the entire stump as far as the mid thigh. A posterior plaster splint is applied extending from the mid thigh to the anterior margin of the stump holding the knee in extension this provides adequate immobilization and protection to the part until healing of the tissues is completed

Amputations Through the Upper Third of the Leg As recorded previously amputations *through this level fail to provide* a lever below the knee joint which possesses the efficiency comparable with amputations through the middle third of the leg Nevertheless amputations at this level are predicated *on the same principles as those* through the middle third Fitting of a prosthesis to the short stump is exceedingly difficult moreover the stump has a tendency to lift itself out of the prosthesis This is *especially true if the hamstrings are left* intact As in amputations with a stump of ideal length weight is borne on the metaphyseal flare of the tibia the fibula is of no functional value and its excision permits a better fit of the artificial limb *Construction* of a short stump is difficult because of the lack of adequate soft tissues The sutures line cannot be placed at will however preferably it should be placed posteriorly or laterally never on the anterior surface of the tibia where it will be *subjected to pres*sure from the prosthesis It may be extremely difficult to obtain sufficient fascial tissue to provide a covering for the end of the stump If possible the posterior fascia *of the gastrocnemius muscle should be uti*lized for this purpose otherwise the fascia from the anterior and lateral aspects of the leg may be employed.

Clinical experience discloses that excision *of the fibula is desirable in amputations* at this level It removal facilitates fitting of a prosthesis and also reduces the incidence of unfavorable sequelae such as the formation of painful bursae painful areas on the stump resulting from a poor fit and even ulcerations of the stump It is preferable to excise the fibula in toto from below at the time of the primary amputation The tibia is treated in the usual manner In order to increase the efficiency of the short stump as a lever and to facilitate fitting a prosthesis some surgeons (Blair and Morris) advocate severance of all the hamstring muscles at the level of the knee joint the sartorius muscle is left intact As a result of this procedure flexion at the knee is not *seriously affected and recurvatum deform*ity does not ensue

From the aforementioned remarks it becomes apparent that amputations through the upper third of the leg present many *technical and mechanical problems* These problems differ in each individual case their solution is dependent upon the skill of the operator and comprehension of the functional mechanics of the stump to be *constructed and the prosthesis* to be worn

Bent Knee Amputations. As noted previously this type of stump is capable of great endurance and can be adapted readily to a prosthesis similar in design to that *employed in end bearing amputations* It is less likely to develop the unpleasant com

plications encountered so frequently in other end bearing stumps and is desirable if a peg leg is to be worn On the other hand the unsightly appearance of the prosthesis in the region of the knee makes this stump undesirable in women The indications for this amputation are instances wherein the lack of tissue precludes the formation of a satisfactory stump capable of utilizing the knee joint and amputation above the knee joint is contraindicated in the presence of flexion contractures of the knee which can not be corrected in growing children in whom a functioning below the knee stump cannot be salvaged and preservation of the distal femoral epiphysis is essential to en sure growth of the femur

As in short below the knee amputations no special technic can be described Each case must be dealt with as an individual problem However the surgeon should strive to meet certain requisites. The knee must be flexed to a right angle a stump measuring 1 to 2 inches below the popliteal space is sufficient the anterior surface of the tibia which bears the weight must be covered by normal pliable skin and free of any bony projections the popliteal space should be lined with normal skin and be free of scars and fibrous tissue and the suture line should be at the end of the stump

Disarticulation of the Knee Joint. Dis articulation of the knee joint is not a popu lar procedure Clinical experience discloses that a prosthesis is fitted with great diffi culty to the bulbous end of the femur and unless the fit is a perfect one, areas on the stump which are subjected to pressure tend to break down. On the other hand Rogers pointed out some of the advantages of dis articulation if a satisfactory fit is attained The broad end of the femur provides an excellent natural weight-bearing surface and is insensitive the soft tissues covering the stump adapt themselves readily to weight bearing the length of the limb is adequate to activate a prosthesis the stump consist ing of the entire femur, retains in toto its muscular apparatus, thereby ensuring excel lent control, the shape of the end of the stump allows some patients to wear a pros thesis without a pelvic band, circulation of the terminal region of the stump is excel lent and normal length of the femur is ensured in children by preservation of the distal femoral epiphysis The cases en countered by the author and recorded in Chapter 7 Congenital and Acquired De formities " support the aforementioned ob- servations In children this method should supplant above-the knee amputations when no contraindications exist

TECHNIC (ROGERS) The position of the surgeon is on the side opposite the extrem ity to be disarticulated, the patient lies in the supine position with the knee flexed Two broad skin flaps are made—a long anterior flap extending 1 inch distal to the tubercle of the tibia and a short posterior flap extending 1 inch distal to the flexor crease of the knee Deep dissection is per formed first in the medial aspect of the knee, the tendons of the 4 medial ham string muscles are identified and sectioned close to the point of insertion The popliteal fossa is now accessible the popliteal artery and vein are isolated and doubly ligated and severed just distal to the origin of the superior geniculate arteries the tibial nerve is located drawn distally and sectioned The deep fascia and the capsule of the joint are divided in the line of the skin incision the deep incision continues across the patellar tendon close to the tibial tubercle. Now, the anterior flap comprises skin patella, patel lar tendon and synovial membrane On the lateral aspect of the knee the biceps tendon and the iliotibial band are dissected free and divided close to their insertions the per oneal nerve is readily identified drawn down and severed By reflecting the pos- terior flap upward the collateral and the cruciate ligaments are made accessible these are divided close to their femoral at tachments. Disarticulation is completed by

sectioning the heads of origin of the gastrocnemius muscle close to the posterior surface of the femur

Without undue tension the muscles of the thigh are attached to the end of the stump The patella is treated in one of two ways it may be mortised into a groove on the anterior surface of the femur or its articular cartilage is removed and its raw surface is opposed to a similarly prepared area on the femur to which it is fixed with a screw or a nail The patellar tendon is drawn posteriorly within the intracondylar groove and fastened to the ends of the tendons of the hamstring muscles the iliotibial band and the tendon of the sartorius are fixed to the fascial portion of the extensor apparatus the synovial membrane and the articular cartilage remain intact Finally the fascial layers and the skin flaps are approximated with interrupted sutures

End Bearing Amputations. These amputations allow the patient to carry his full weight on the end of the stump They differ from amputations of the thigh above the supracondylar region which are so designed that with a specially adapted prosthesis the greater part of the weight is borne on the tuberosity of the ischium In order to construct a good functioning stump the surgeon must know the basic principles which ensure the successful creation of a functional stump As pointed out by Slocum the stump should be of sufficient length to provide an efficient lever to control the limb Amputations from the level of the knee joint to the supracondylar region meet this requirement this is not true of amputations above the juncture of the middle and the lower thirds of the thigh Locomotion is achieved by preservation of the muscular apparatus of the stump this entails retaining the natural length of the individual muscles preserving their origin and providing an insertion to bone Moreover the lateral surface must be able to transfer effectively the motor leverage of the stump to the artificial limb An ide stump can propel, rotate and lift a prosthesis with ease The end of the stump may be rounded or flat but in each instance the supporting surface should be smooth and parallel with the ground so that the load is distributed evenly and not concentrated on one small area It becomes apparent that the greater the weight-bearing surface the less pressure is made per unit of surface and the greater the endurance of the soft tissue covering The difficulty in fitting a prosthesis to a bulky bearing area, such as one encounters in disarticulations of the knee is somewhat counterbalanced by the advantages recorded previously of a large bearing end and the availability of skillfully and efficiently constructed artificial limbs This difficulty becomes progressively less in amputations at higher levels in the supracondylar region Depending on the technic employed the end of the bone may be covered by the quadriceps tendon the patella or the patellar bed in the extensor fascia after the patella has been enucleated the skin should be pliable free of cicatrix and possessing normal sensation and adequate blood supply In the body there are certain tissues which are naturally designed to withstand outside pressure if possible an attempt should be made to utilize this material as coverage for the end of the stump Rogers enumerated these highly specialized tissues as follows finely trabeculated cancellous bone surrounded by a thin cortex, and covered by either hyaline cartilage or adherent periosteum the tendinous origins or insertions of muscles secretory pouches such as joint cavities and bursae areolar connective tissue and skin —the last two of a congenitally specialized variety"

ROUNDED EPICONDYLAR TENDOPLASTIC AMPUTATION (SLOCUM) (Fig 424) The essential features of this operation are the creation of a broad bearing end which is rounded to facilitate fitting of an artificial limb apposition of the patellar bed in th apparatus to the end of the

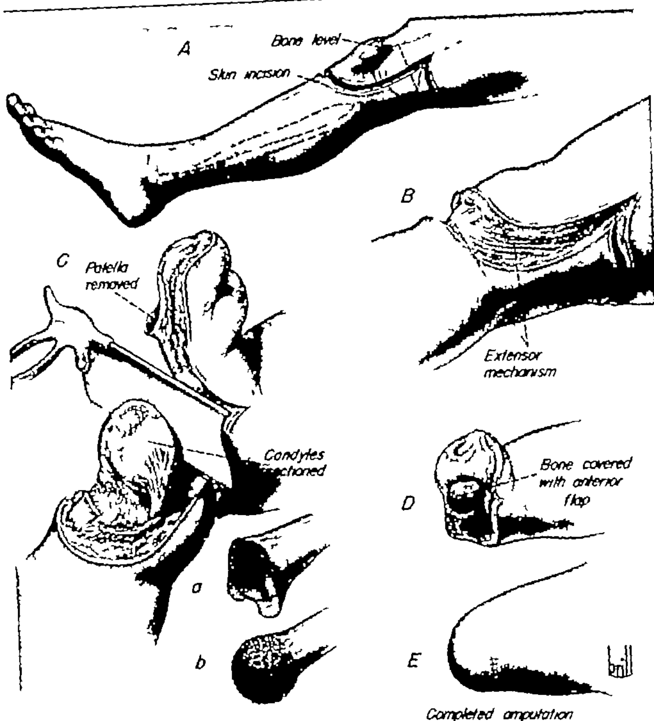


FIG. 424 (A to E) Steps in rounded epicondylar tendoplastic amputation (Slocum)

raw bone surface Slocum points out that the finished stump is similar to that produced by the Stokes Gritti procedure, but the hazard of failure of fusion between the femur and the patella is eliminated

With the patient in the supine position the anterior skin incision begins on the medial aspect of the leg opposite the ad ductor tubercle of the medial epicondyle it continues distal across the joint line, then swings laterally, crossing the front of the knee at the level of the insertion of the patellar tendon to the tubercle of the tibia Then it continues proximally along the lat eral aspect of the knee to terminate at the upper border of the lateral epicondyle of the femur The posterior incision joins the two ends of the anterior incision forming a gentle arc directed downward the result ing posterior flap measures ¾ inch. The

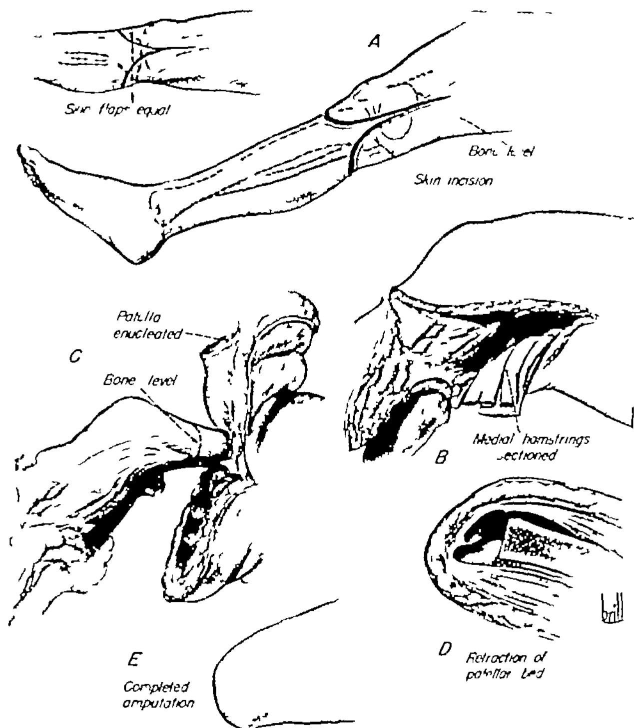


FIG 425 (A to E) Steps in supracondylar amputation (Callander)

anterior aspect of the joint is exposed by deepening the incision through the fascia and the tendon The anterior flap is now reflected upward and the patella is enucleated by sharp dissection. All excess fat and the synovial membrane about the patellar bed are trimmed away At the level of the femoral condyles the bone is sectioned so that the weight bearing surface is parallel with the ground when the patient is in the erect position The resulting base of the femur is broad and irregular it must be rounded and smoothed until it is roughly hemispherical in shape except for its broad

flattened base. This is achieved by beveling the edges of the cut bone at an angle of 45° beginning ½ inch from the periphery All sharp edges and spicules of bone are smoothed with a bone file By displacing downward the severed femoral condyles, the soft tissues on the posterior aspect of the thigh are brought into view The popliteal artery and vein are identified isolated doubly ligated and divided the sciatic nerve (or the tibial and the common per oneal nerves) is divided above the level of the end of the bone A fine ligature around the nerve will prevent bleeding from the small vessel which lies with the nerve trunk Next the hamstring muscles are dissected free and severed at the bone level The posterior fascia of the thigh is now clearly visualized, it is sectioned in an anteroposterior direction ¼ inch distal to the retracted skin of the posterior flap The tourniquet is now released and all bleeding points are controlled

When the anterior flap is drawn posteriorly, the patellar bed fits snugly over the end of the bone the tendinous portion of the flap is fixed to the posterior fascia by interrupted sutures The skin flaps are approximated by interrupted skin sutures A drain is placed in the depth of the wound dry sterile gauze dressings are applied over the stump and compression is made by an elastic bandage over sheet wadding After 48 to 72 hours the drain is removed and compression by elastic bandaging is con tinued until shrinkage of the stump is complete

CALLANDER AMPUTATION (Fig 425) Clinical experience discloses that this is the procedure of choice for peripheral vascular disease necessitating an amputation above the level of the foot The essential features of the procedure are extra long anterior and posterior flaps of equal length provi sion for adequate drainage from the end of the stump severance of all muscles through their tendinous insertions and the absence of any deep sutures. Although the flaps appear to be unusually long at the end of the operation subsequent retraction of the tissues leaves no redundant or bulky masses over the stump The posterior tissues re tract a greater distance than the anterior, hence drawing the suture line proximally on the posterior aspect of the stump No tourni quet is required in this amputation, because it is performed through vascular planes

The patient is placed in the supine posi tion, a sandbag under the popliteal space supports the limb and flexes the knee 150° The surgeon takes his place on the side of the operating table opposite the leg to be amputated Starting on the medial aspect of the thigh 3 fingerbreadths above the medial femoral condyle, the skin incision passes distally in the interval between the vastus medialis and the sartorius muscles this groove is readily discernible with the knee flexed The incision swings downward and outward to the anterior aspect of the upper end of the tibia just distal to the in sertion of the patellar tendon into the tubercle of the tibia. At this point the thigh is rotated medially and a second skin incision is made on the lateral aspect of the thigh beginning 3 fingerbreadths above the lateral condyle of the femur, it continues down ward and inward in the anterior region of the groove between the tendinous fascia lata and the biceps femoris tendon and joins the medial incision over the tibial tubercle Similar incisions are made on the posterior aspect of the leg outlining a posterior flap equal in length to the anterior, the distal point of the posterior incision lies at the mid line of the calf behind the tibial tubercle Next, both incisions are carried down to the level of the fascia. Now the limb is rotated externally and the medial fascia is divided All the inner hamstring muscles are identified and freed by blunt dissection the tendons are severed at their tibial insertions in an anteroposterior direction first the sartorius then the gracilis the semimem branosus and the semitendinosus also, the tendinous portion of the adductor magnus

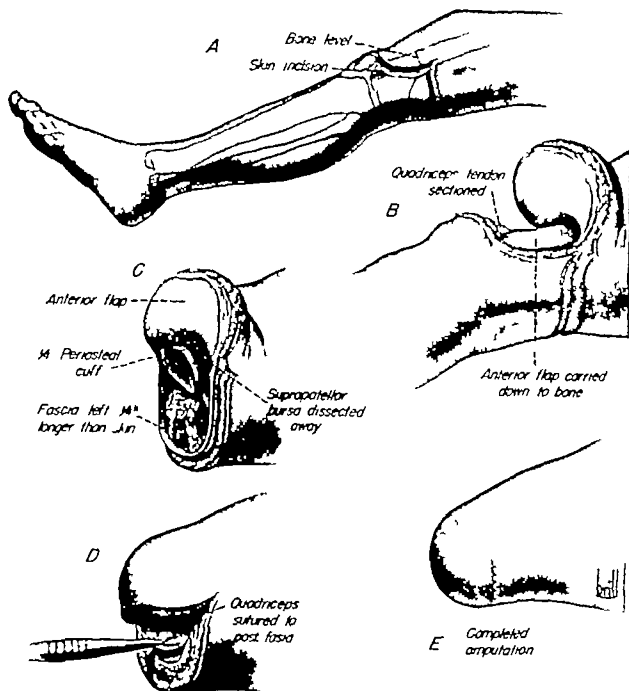


FIG 426 (A to E) Steps in periosteal supracondylar tendoplastic amputation (Kirk)

muscle is divided at its point of insertion into the adductor tubercle The femoral artery and vein are isolated by finger dissection clamped doubly ligated and divided at the most distal point possible in the popliteal fossae The sciatic nerve (or its branches the tibial and the common peroneal nerves) is identified freed of surrounding areolar tissue and sectioned A fine ligature around the end of the nerve ensures against bleeding from the small vessel found in its substance The limb is now rotated internally and the deep fascia on the lateral aspect of the thigh together with the fibers of the fascia lata are sectioned the tendon of the biceps femoris muscle is dissected free and severed at its point of insertion into the head of the fibula The posterior

incision is carried to the aponeurosis of the gastrocnemius muscle With the knee in the extended position the anterior incision is deepened through the capsule, the synovial membrane and the patellar tendon in the line of the skin incision. The resulting anterior flap comprising the extensor fascia, the patella and the patellar tendon is reflected upward by sharp dissection the patella is removed from its bed, the synovial lining is left intact Immediately proximal to the adductor tubercle the femur is sectioned transversely, at this level the transverse diameter of the femur approaches roughly that of the patellar bed in the extensor apparatus the margins of the cut bone end are made smooth with a bone file. Both flaps now extend approximately one or more inches distal to the bone level, they are brought together loosely and approximately by 4 or 6 interrupted sutures The remarkable feature of this procedure is the rapidity with which the flaps retract within 7 to 10 days the flaps fit the end of the bone snugly and the suture line is pulled upward on the posterior aspect of the stump by the hamstring muscles After the stump is covered with dry sterile dressings a posterior plaster splint is applied For several days considerable serous material drains from the wound requiring daily dressings

Periosteal Supracondylar Tendoplastic Amputation (Kirk) (Fig 426) The distinguishing features of this amputation are the creation of a long anterior and a short posterior flap in the relationship of 4 to 1 the bone is sectioned 1¼ inches above the articular surface on the anterior aspect of the femur and forms a tapering conical stump to which a prosthesis can be fitted readily Beginning on the medial aspect of the thigh just proximal to the intended bone level and at a point midway between the anterior and the posterior surfaces of the femur the skin incision continues distally and outward crossing the anterior aspect of the thigh just distal to the base of the patella it curves proximally on the midlateral aspect of the thigh to terminate opposite the starting point on the medial aspect of the thigh The posterior skin flap is made by joining the upper ends of the anterior incision by an incision with a convexity directed downward the flap measures in length at its most distal point one fourth the length of the anterior flap After both skin incisions are carried down to the underlying fascia the anterior incision is deepened to the bone slightly above the line of the retracted skin, the quadriceps tendon is sectioned at its insertion into the patella. The resulting anterior flap, comprising skin and musculotendinous tissue is reflected upward, exposing the synovial lining and the suprapatellar pouch, these structures are removed by sharp dissection

On a line ¼ inch below the retracted skin the posterior fascia of the thigh is sectioned the remaining posterior soft tissues, consisting mostly of muscles, are severed to the bone so that their proximal cut ends lie at the predetermined bone level the flap is then reflected upward Before the bone is sectioned a circular cut is made in the periosteum at the saw level, and a ¼ inch periosteal cuff is excised The bone is sectioned transversely in such a manner that its cut surface parallels the ground when the patient is standing To accomplish this the normal deviation of the femur must be taken into consideration Next the femoral artery and vein are identified clamped doubly ligated and cut the sciatic nerve (or its branches, the tibial and the common peroneal nerves) is isolated drawn downward and cut. A fine ligature around the nerve will control any bleeding from within its substance all other nerves are pulled down cut and allowed to retract. If a tourniquet is employed it is now released and all bleeding points are controlled Closure is achieved by approximating the fasciae of the two flaps by interrupted sutures If the amputation is performed correctly the quadriceps tendon falls directly over the end of the bone. The skin edges are closed

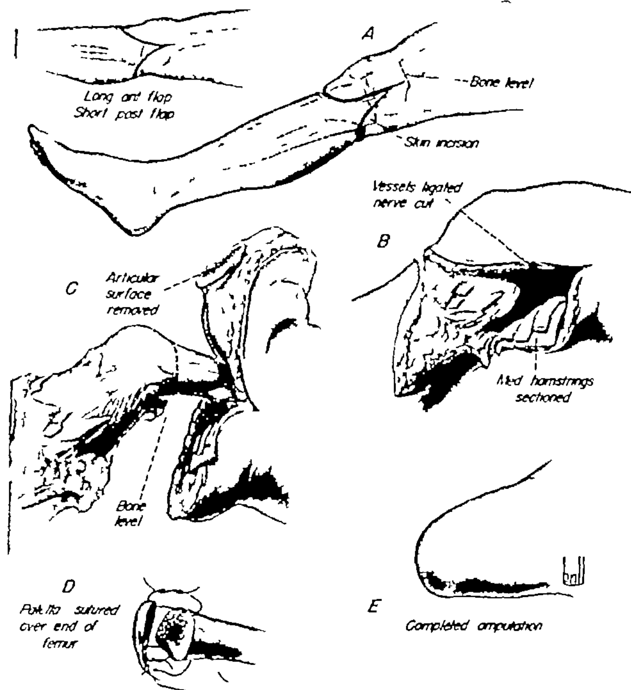


FIG 427 Osteoplastic amputation (Stokes Gritti)

with interrupted skin sutures and drains are inserted on both ends of the wound (these are removed at the end of 48 to 72 hours) The stump is covered with sterile dry gauze dressings and compression is made by elastic bandages

OSTEOPLASTIC AMPUTATION (STOKES GRITTI) (Fig 427) In the United States this amputation is not performed frequently however the Canadians prefer this to all other types of end bearing amputations The chief objection to the procedure is frequent failure to achieve bony union between the end of the femur and the patella Weight bearing is made directly on the anterior surface of the patella

Beginning at a point midway between the anterior and the posterior surfaces of the

thigh and 1 inch proximal to the base of the patella, the skin incision curves distally to a point ½ inch below the apex of the patella, it continues across the front of the knee joint and swings upward on the medial aspect of the thigh to terminate 1 inch above the superior border of the patella By connecting the upper ends of the anterior incision the posterior flap is formed It measures approximately ½ inch at its most distal point in the popliteal space The anterior incision is carried into the joint, dividing the capsule the patellar tendon and the synovial membrane the resulting flap is reflected upward Next, any redundant synovial tissue is trimmed away, and the posterior one half of the patella is removed This includes the articular cartilage of the patella and a section of the subchondral bone After the posterior skin flap is retracted upward the muscles are sectioned in a slightly oblique plane, beginning proximally near the skin and ending distally immediately above the condyles of the femur Next the femoral vessels are identified clamped, doubly ligated and severed, the sciatic nerve (or its branches) is drawn downward and divided, a fine ligature is passed around the nerve end to control postoperative bleeding

In the supracondylar region a level is chosen the base of which corresponds in size to that of the patella, at this site the femur is divided transversely in a plane parallel with the ground when the patient is standing The anterior flap is drawn posteriorly over the stump so that the two raw bony surfaces are in apposition. The patella is fixed to the end of the femur by 2 stout catgut sutures, one passing anteriorly and one posteriorly through drill holes made in both bones. The patellar tendon and the periosteum on the posterior surface of the femur are approximated by interrupted sutures The skin edges are closed by interrupted skin sutures A drain is inserted into either side of the wound After the stump is covered with sterile gauze dressings an elastic bandage is applied from the end of the stump to the groin, making uniform compression The drains are removed at the end of 48 to 72 hours

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14

Bone Neoplasms in the Region of the Knee Joint

GENERAL CONSIDERATIONS

It is not the aim of the author in this chapter to delve into the controversial theories of the origin and the histology of bone tumors in general but to deal with the diagnosis and the treatment of these lesions Primary neoplasms both benign and malignant, and metastatic lesions are encountered frequently in the region of the knee joint Tumors in this region do not differ from those encountered in other parts of the body However, failure to make an accurate diagnosis and to institute adequate therapy is apt to cost the patient a limb Although the seriousness of such an error is far less than one made in the region of the shoulder girdle the loss of a lower limb is a grave handicap to the individual Knowledge of the clinical course and of the ro graphic and histologic characteri bone tumors will increase diagnostic and reduce to a minimum the inci the above surgical tragedies Moreo knowledge provides the surgeon working armamentarium which pe intelligent approach to the problem pedites formulation of an early d All these factors play an importan the ultimate outcome of the indivi *on hand. The great number of poo* aged cases which are seen every ye tumor clinics is a serious reflectio profession as a whole. To educate t to the importance of early diagnosi cer is most essential, but it is ev important to educate the physician

Table 9 Classification of Bone Tumors (Coley)

Malignant	Benign
Fibrosarcoma of bone	Nonosteogenic fibroma of bone
Osteogenic sarcoma	Osteoma
	Osteoid osteoma
	Exostosis
Primary chondrosarcoma	Chondroma
Secondary chondromyxosarcoma	
Malignant giant-cell tumor	Benign giant-cell tumor
	Benign chondroblastoma (Codman's eal chondromatous) (giant-cell tur
	Unicameral bone cyst
Endothelioma (Ewing's sarcoma)	Cavernous angioma
Angiosarcoma	Plexiform angioma
Myeloma { plasma-cell myeloma, myelocytoma, erythroblastoma, lymphocytoma	
Reticulum-cell sarcoma	
Liposarcoma	

TABLE 10 (LICHTENSTEIN)

BENIGN TUMORS OF BONE			MALIGNANT COUNTERPART (if any)	MALIGNANT TUMORS OF BONE (Arising through malignant change or independently)
Cartilage cell or cartilage-forming connective-tissue derivation	PERIPHERAL	Osteocartilaginous exostosis (multiple exostosis)	PERIPHERAL CHONDROSARCOMA	Chondrosarcoma
Cartilage cell or cartilage-forming connective-tissue derivation	CENTRAL	Enchondroma (skeletal enchondromatosis)	CENTRAL CHONDROSARCOMA	Chondrosarcoma
Cartilage cell or cartilage-forming connective-tissue derivation	CENTRAL	Benign chondroblastoma	Not known	
Cartilage cell or cartilage-forming connective-tissue derivation	CENTRAL	Chondromyxoid fibroma	Not known	
Osteoblastic derivation		Osteoma	Not known	Osteogenic sarcoma
Osteoblastic derivation		Osteoid osteoma	Not known	Osteogenic sarcoma
Osteoblastic derivation		Osteogenic fibroma	Not known	Osteogenic sarcoma
Osteoblastic derivation		Other osteoid tissue-forming tumors	Osteogenic sarcoma	Osteogenic sarcoma
Nonosteoblastic connective-tissue derivation		Nonosteogenic fibroma	Not known	Fibrosarcoma
Nonosteoblastic connective-tissue derivation		Least aggressive giant cell tumors	More aggressive and malignant giant-cell tumors	Frankly malignant giant-cell tumors
Mesenchymal connective-tissue origin		—		Ewing's sarcoma
Hematopoietic origin		—		Multiple myeloma
Hematopoietic origin		—		Chronic myeloid leukemia
Hematopoietic origin		—		Acute leukemias
Hematopoietic origin		—		Malignant lymphoma: Reticulum-cell sarcoma
Hematopoietic origin		—		Malignant lymphoma: Lymphosarcoma
Hematopoietic origin		—		Malignant lymphoma: Hodgkin's disease
Nerve origin		Neurofibroma	Malignant schwannoma	
Nerve origin		Neurilemmoma	Malignant schwannoma	
Vascular origin		Hemangioma	Hemangio-endothelioma	Hemangio-endothelioma
Vascular origin		Hemangiopericytoma (Glomus)	Hemangio-endothelioma	Hemangio-endothelioma
Fat-cell origin		—		Liposarcoma (?)
Notochordal derivation		—		Chordoma
Adamantine or possibly basal cell derivation		—		So-called adamantinoma

CLASSIFICATION OF BONE NEOPLASMS

Since the classification conceived by Ewing in 1939 for the Registry of Bone Sarcoma of the American College of Surgeons numerous classifications of bone tumors have appeared in the literature. A survey of these classifications leaves the reader confused because there is total lack of agreement among the investigators on the basis of a classification Some workers strive to classify bone lesions on their anatomic and histologic features others base their classification on pathologic and roentgenographic characteristics Within the past decade there has been a uniform trend to classify primary bone tumors in accordance with the predominant cell or tissue contained in the neoplasm and springing from the undifferentiated germ cells of bone This is applied not only to bone tumors per se but also to tumors arising from the accessory tissues of bone as bone marrow reticulo endothelial system and connective tissue of the marrow In line with the aforementioned trend Coley modified the revised classification of the Registry of Bone Sarcoma of the American College of Surgeons he included both benign and malignant neoplasms (Table 9) More recently, Lichtenstein evolved an even more comprehensive classification of primary neoplasms of bone (Table 10) In it he attempts to indicate the malignant counterpart, if one exists, of the benign lesion

DIAGNOSIS OF BONE NEOPLASMS

History

Of great importance in establishing a diagnosis of bone tumor is a carefully taken history It should elicit the significant features of the case in chronologic order with particular emphasis laid on the age of the patient the time interval of the manifested symptoms and the rapidity of growth of the lesion This information together with other diagnostic aids, will allow the correct diagnosis to be made in the great majority of the cases Although the factor of heredity plays a dubious role in the etiology of bone tumors, certain lesions such as multiple osteochondromas and other tumors of cartilaginous derivation appear to have a hereditary background It is an established clinical fact that rapidly growing tumors regardless of the patient s age or the site of the tumor, must be regarded as very malignant lesions On the other hand, slowly growing tumors are less malignant If a tumor has existed for a long time without increase in size and then begins to manifest evidence of enlargement, the increased activity is usually indicative of secondary malignant changes in a benign neoplasm.

Past History Many infectious diseases may implicate the osseous system producing lesions not unlike true bone tumors It becomes apparent that the past history must be scrutinized meticulously for the previous existence of such lesions. Syphilis is the most common offender in this category, it may simulate many of the known bone neoplasms Other infectious processes capable of confusing the clinical picture are tuberculosis, osteomyelitis, typhoid fever and brucellosis The author has encountered two cases of tuberculosis of the shafts of long bones appearing in the form of discrete cystic lesions without clinical implication of the lungs or other viscera, both cases presented unusually difficult diagnostic problems. The diagnosis was established by histologic study of the material obtained from the lesions. Metabolic and deficiency diseases such as gout rickets and scurvy, produce bone lesions

In older individuals it is of utmost importance to elicit the presence or the absence of Paget's disease of bone and of tumors of any region of the body, either past or present. It is not uncommon for metastatic bone lesions to occur many years after the ablation of carcinoma of the thyroid gland or the breast.

Past history will reveal the presence or the absence of strains and repeated trauma to the affected part This may have some bearing on the ultimate identity of the lesion.

Injury

Trauma antedates the symptoms and the local manifestations in a large group of cases Its importance as an etiologic factor of bone tumors is of doubtful value however, in many instances it serves to make the patient cognizant of an existing lesion. Occasionally the first manifestation of a neoplasm is a pathologic fracture It is generally recognized that a single trauma regardless of the degree of severity is not the prime causative agent responsible for the development of neoplasms of bone Nevertheless every effort should be made to record a detailed account of the injury or accident such as its time and manner of occurrence demonstrable local evidence of the injury at the time of examination, the degree of disability resulting from the incident and the subsequent course of the pathologic disorder Such data may be of particular importance should the case assume medicolegal proportions.

Age

The age period wherein bone neoplasms appear is of special significance in establishing a correct diagnosis this is particularly true of osteogenic sarcoma The study of Badgley and Batts disclosed that the greatest number of osteogenic sarcomas were encountered in the second decade Christensen recorded that two thirds of 441 cases of bone sarcoma occurred between 10 and 30 and one third over 30 years also that the very young and the very old are rarely affected with bone sarcoma

Codman pointed out that osteogenic sarcoma in individuals around 50 years of age is usually indicative of sarcomatous changes superimposed on Paget's disease of bone Bird found that 14 per cent of all cases of Paget's disease undergo sarcomatous transformation.

Of interest is the relationship of bone cysts and giant-cell tumors to age Bone cysts make their appearance before closure of the epiphyseal disk giant-cell tumors are encountered after the epiphysis has united Plasma-cell myeloma is rarely encountered under the age of 40 although the author knows of one case which was 30 years of age when the diagnosis was established by histologic study As a rule metastatic lesions are found past middle life but they occasionally are seen in patients under 20

Site of the Tumor

Some neoplasms of bone discloses a predilection for specific regions of the osseous system Knowledge of this characteristic is a valuable aid in making a diagnosis. Osteogenic sarcoma is encountered more frequently in the region of the knee than in any other part of the body Approximately 42 per cent of all sarcomas of bone are found in the lower end of the femur and the upper end of the tibia and the fibula. Over 57 per cent of all giant-cell tumors are encountered in the aforementioned areas of the knee joint Solitary bone cysts are usually observed in the diaphysis close to the metaphysis while giant-cell tumors are observed in the epiphyseal region after ossification of the epiphyseal plate has occurred Osteogenic sarcomas most frequently implicate the ends of the shafts of long bones and the metaphyseal region while Ewing's tumors involve the shafts The most common sites for benign chondroblastoma in the order of frequency are the lower end of the femur the upper end of the tibia and the upper end of the humerus (Fig 428)

Pain

Pain without apparent cause is a frequent subjective manifestation of bone neoplasm. In the early stages of the disease it is exceedingly variable It may be mild and present only on activity or intermittent so

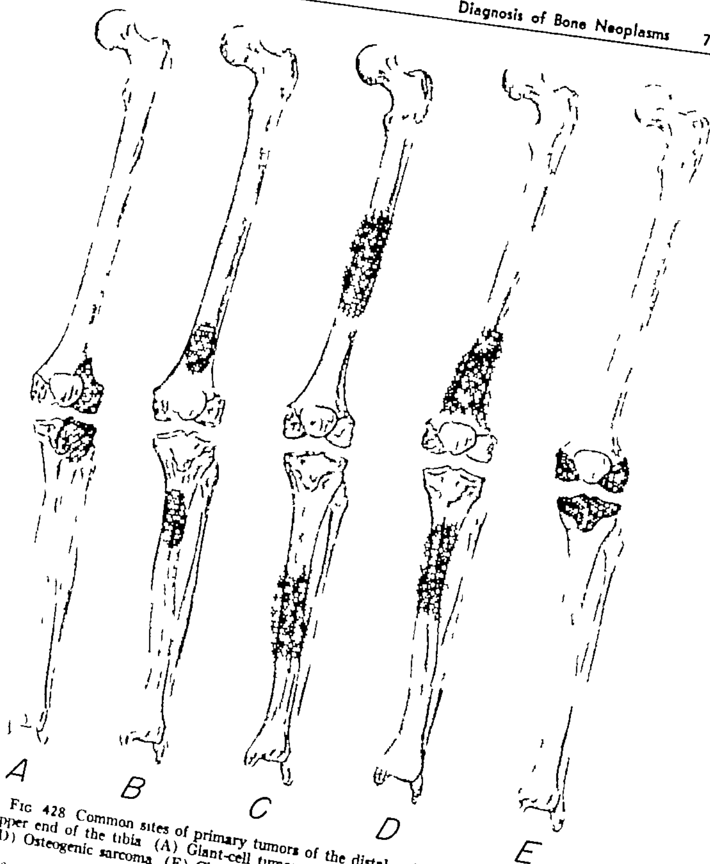


FIG 428 Common sites of primary tumors of the distal end of the femur and the upper end of the tibia (A) Giant-cell tumor (B) Bone cysts. (C) Ewing s tumor (D) Osteogenic sarcoma (E) Chondrosarcoma.

that its seriousness is not understood by the patient or the physician Generally its onset is insidious however at times it is ushered in abruptly and may be associated with pronounced systemic reaction not unlike an infectious process such as acute osteomyelitis Not infrequently Ewing s tumor and highly malignant, rapidly growing bone sarcomas

does not indicate the benign or malignant character of a tumor Many small tumors are not detected until after there is clinical evidence of metastasis The size and the configuration of neoplasms vary greatly As in the region of the shoulder, chondrosarcomas are usually the largest tumors in the vicinity of the knee joint.

Generally, tumors arising in the medullary and the cortical portions of bone encounter greater resistance to growth and expansion than those arising from the surface of bone or beneath the periosteum the latter grow more rapidly than the former and reach greater dimensions. Large tumors and tumors implicating the adjacent soft tissues may interfere with the venous and the lymphatic circulations of the limb thence pronounced enlargement of the extremity distal to the lesion may occur

The rate of enlargement in slowly growing tumors may be determined by careful circular measurements of the part. To avoid errors, the same levels above and below the apex of the patella should be used at each subsequent measurement

Body Reaction

Although most bone neoplasms do not produce clinically demonstrable systematic reactions occasionally some malignant lesions are ushered in with all the clinical manifestations of an acute infection Ewing's tumor falls into this category Before this characteristic of Ewing's tumor was widely known many cases were subjected erroneously to operative procedures under the diagnosis of acute osteomyelitis Unfortunately roentgenographic study in these cases may fail to uncover the true nature of the lesion The clinical features of osteoid osteoma simulate those of Garré's disease and Brodie's abscess all these lesions are associated with intense deeply seated pain and roentgenographically exhibit localized increased bone density It is common knowledge that many cases of osteoid osteoma have been operated upon under a mistaken diagnosis There are 3 cases of osteoid osteoma in the author's files which were subjected to more than one surgical procedure before the true diagnosis was established Osteoid osteoma is a relatively common lesion in the femurs of adolescents, and in these cases it may be responsible for referred pain in the knee joint One such case came to the writer's attention which had been treated as synovitis of the knee joint for several months Roentgenograms including the middle one third of the femur disclosed the true identity of the lesion

In general, the physical status of a patient with sarcoma is better than that of a patient with carcinoma, except in the terminal phases Anemia in varying degrees, which increases in intensity as the tumor progresses is a frequent concomitant feature of carcinoma. Severe pain in bone neoplasms may interfere with the patient's sleep and rest, they become irritable and extremely apprehensive

Pulsating Tumors

Pulsation is an exceedingly rare characteristic of primary bone tumors, implicating the ends or the shafts of long bones Occasionally, highly vascular neoplasms exhibit this feature On the other hand, osteolytic metastatic lesions from renal and thyroid cancer may produce a pulsating tumor Codman put forth the premise that pulsation of a tumor mass destroys the surrounding bone and causes expansion of the remaining thin bony shell The pulsating bone marrow tends to restrain extension of the tumor down the medullary canal

Although the number is small some pulsating giant-cell tumors have been recorded in the literature Histologically these neoplasms in no way differ from nonpulsating giant-cell tumors however, it is believed that their rate of growth is more rapid and they exhibit a greater tendency toward recurrence after therapy either by surgery or irradiation.

Roentgenographic Studies

Roentgenographic study plays a major

role in arriving at the correct diagnosis of bone neoplasms It is more important than physical examination and second only in importance to histologic study of the bone lesions In most instances roentgenograms taken in the anteroposterior the lateral and the oblique views provide the desired information Occasionally, exposures other than the aforementioned conventional ones may be necessary to give more nearly accurate and detailed data In addition stereoscopic and laminographic exposures may add much pertinent information when more difficult diagnostic problems arise

As a rule bone tumors produce certain alterations in bone and the adjacent soft tissues which are characteristic of the lesions and are demonstrable roentgenographically this is especially true of benign lesions One well versed in these characteristic features is able to make a correct diagnosis in a large number of cases, and a tentative one in others It is true that even what appears to be an obvious roentgenographic diagnosis may bring forth diversified interpretations from different roentgenologists It is also true that some bone neoplasms give rise to bizarre roentgenograms which defy the most competent roentgenologist many lesions mimic the features of others making a correct diagnosis by roentgenographic study alone impossible It has been demonstrated frequently that many such lesions also exhibit histologic patterns that fail to conform to any specific category According to Coley there is a 14 to 20 per cent error in roentgenographic diagnosis when checked by histologic examination

Some of the diseases of bone which test and even defy the acumen of the roentgenologist are syphilis of bone which may take on the roentgenographic features of primary osteogenic sarcoma Ewing's tumor which resembles closely acute osteomyelitis cystic tuberculosis of bone which simulates metastatic carcinoma of bone single metastatic lesions which may be interpreted erroneously as primary osteolytic bone sarcoma osteoid osteoma which may be difficult to distinguish from a bone abscess or Garré's disease, and myositis ossificans, which may be mistaken for periosteal sarcoma In addition, Ewing's tumor may be mistaken for metastatic bone lesions of neuroblastoma.

The appearance of a lesion in one bone makes a general skeletal survey imperative This often uncovers the presence of other lesions or even general skeletal involvement and may establish the identity of bizarre neoplasms An investigation of the entire osseous system is also indicated in lesions suggestive of multiple myeloma parathyroid disease, fibrous dysplasia of bone multiple exostosis and metastatic bone lesions

An essential part of all roentgenographic surveys is examination of the chest. Occasionally, the only evidence of the true nature of a bone tumor is the presence of metastatic nodules in the lungs Repeated examinations of the chest should be done at regular intervals in order to check the diagnosis of a bone lesion and to follow the course of its behavior regardless of the choice of therapy instituted

Laboratory Examination

It is definitely established that certain diseases affecting bone are associated with demonstrable alterations in the chemistry of blood and urine This knowledge is of significant value in arriving at a correct diagnosis of bone lesions Notably among the workers who have made valuable contributions to this aspect of bone study are Albright Reifenstein Woodard Bodansky Gutman and Kutscher A well-conducted laboratory investigation comprises (1) complete blood count (2) Wassermann reaction of blood and spinal fluid (3) serum calcium level (4) serum phosphorous level (5) serum phosphatase level and (6) test for Bence-Jones bodies in the urine In addition the following tests may disclose some pertinent abnormalities in the body chemistry (1) sugar determinations, (2) uric

acid level which is elevated in gout, and (3) blood protein level, which may be greatly elevated in multiple myeloma.

The true interpretation of elevated phosphate levels is essential to prevent pitfalls in diagnoses of bone neoplasms or other osseous disorders Elevated alkaline phosphatase values do not indicate any specific bone tumor or the malignant nature of bone lesions Instead, they are indicators of new bone formation in the natural course of a reparative process or by a neoplastic primary or secondary bone lesion

High alkaline phosphatase readings are found in growing individuals and in normal reparative processes in which bone is being formed, such as in fractures In certain bone diseases wherein new bone formation is a predominant feature the alkaline phosphatase is elevated Such is the case in osteogenic sarcoma, osteoplastic metastatic carcinoma to bone and Paget's osteitis deformans. Bone diseases characterized by alterations in the normal calcium and phosphorus metabolism may reveal increased alkaline phosphatase levels as in rickets osteomalacia and hyperparathyroid disease As a rule, osteolytic lesions arising from carcinoma do not cause rise in the serum alkaline phosphatase level This is in contrast with osteoplastic lesions from carcinoma particularly cancer of the prostate gland in which the values are invariably high. Coley observed that 75 per cent of all metastatic lesions from the prostate gland were osteoplastic, and the remainder disclosed some new bone formation

A high serum acid phosphatase is a concomitant feature of metastatic bone lesions from carcinoma of the prostate In fact some workers are of the opinion that an increased serum acid phosphatase determination is pathognomonic of cancer of the prostate

Histologic Examination

The aforementioned diagnostic aids discussed will provide sufficient information in the great majority of cases to establish a correct diagnosis However, in a small group the final diagnosis cannot be made on this data The best that one may do is arrive at a tentative diagnosis Histologic examination of the suspected tissue is the last and final diagnostic test at our disposal The tissue for examination may be obtained by surgical or aspiration biopsy

Aspiration Biopsy

This method is preferred to surgical biopsy in many cancer clinics Its simplicity is a distinct advantage and in the hands of experienced workers it yields a relatively high incidence of satisfactory results It provides a simple method to differentiate soft tissue malignancies and chronic inflammatory processes. All surgeons interested in neoplasms should be versed in this method The method does have some disadvantages The material obtained by aspiration may not be adequate to make a diagnosis, tumor cells may be disseminated along the path of the needle hemorrhage may occur within the tumor, favoring metastasis and a negative aspiration does not dismiss definitely the presence of a tumor Also, deeply seated tumors are difficult to reach, and, if surrounded by dense bone the needle may not penetrate into the substance of the tumor The observations of Coley and Snyder are significant. They recorded that in 568 aspiration biopsies of bone performed on 474 individuals there were no immediate complications and no evidence indicating that the procedure had enhanced the development of metastasis Also, in 67 5 per cent of 385 cases of primary and secondary bone neoplasms a specific diagnosis was established by this method 82 per cent of the cases yielded sufficient tissue to permit a diagnosis in 14.5 per cent the tissues were not identified and in 1 case a benign lesion was diagnosed as a malignant tumor

A proved valuable diagnostic aid is aspiration of the sternum or the iliac crests for bone marrow It provides pertinent information in cases of multiple myeloma leukemia and metastatic carcinoma. In some

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clinics aspiration of the iliac crest is pre ferred to sternal puncture

Surgical Biopsy

This method must not be taken lightly and should be performed with gentleness and profound respect for the tissues in volved It always should precede any radi cal procedure particularly amputations. It is the method of choice in some institutions and in some cases it is the only means at one s disposal for obtaining tissue for histologic examination The disadvantages of an open operation are counterbalanced by the assurance that adequate material can be obtained for histologic study If possible the operation should be executed under tourniquet after the desired tissue is re moved the wound is closed in layers. An incision in suspected malignant tissue never should be left open or drained If closure is performed as described above, the chances of disseminating tumor cells and fungation of the tissues are minimized.

BENIGN BONE NEOPLASMS

Osteocartilaginous Exostosis (*Osteochondroma*)

Introduction. Osteochondroma is by far the most common neoplasm of bone Al though it may arise in any bone preformed in cartilage it is most commonly observed in the ends of long tubular bones particu larly in their metaphyseal regions They may occur as single or multiple lesions the latter group is recognized clinically as he reditary deforming dyschondroplasia and is associated with bizarre skeletal deformities such as bending of the bones shortening resulting from interferences with normal bone growth and widening and distortion of the metaphyseal region Tumors in both categories (single or multiple) essentially comprise a mass of bone covered by a car tilaginous cap the base of the tumor protrudes from the surface of the involved bone In a measure the amount of cartilage tissue present in the tumor is responsible for the clinical and the roentgenographic features.

In general, these tumors are considered to be congenital lesions Not infrequently a familial tendency can be traced through several generations. This is especially true of hereditary deforming dyschondroplasia usually observed in the white race Negroes are affected rarely Many workers have stressed the familial characteristics of these tumors notably among these are Ollier Hale, Jansen Ehrenfried and the Vansants. The widening and broadening of the affected metaphyseal regions so frequently observed to be associated with these tumors (more so in the multiple forms) is the result of defective modeling of the bone This theory was set forth by Keith

Etiology The exact origin of these neoplasms is still obscure, in spite of some very convincing conjectures on their histogenesis As noted previously, it is conceded that they are found in bone preformed in cartilage and arise from cartilage According to Geschick ter and Copeland from a histologic view point osteochondromas are merely an ex aggeration of normal bony protuberance destined for the insertion of an important tendon At the juncture of tendon and bone a bony protuberance normally emerges through a defect in the periosteum and joins the tendon which in turn contributes to the formation of the attachment by cartilagi nous ossification within the substance of the tendon Furthermore they maintain that in cases of multiple lesions tags of periosteum in the ends of the tendon proliferate and form cartilaginous and bony outgrowths also associated disturbances and deficien cies in the periosteum in the region of the metaphyses of the affected bones are re sponsible for widening of the metaphyses and inhibition of bone growth These ob servers believe that the tumors are the result of perverted activity of the periosteum a process which is conducive to the formation of aberrant foci of metaplastic cartilage

Site Incidence Age and Sex. The ends



FIG 429 (A, *Left*) Multiple osteochondroma in a female, aged 16 Note the pedunculated configuration of the lesion arising from the posteromedial aspect of the distal end of the femur A similar lesion arises from the posterior aspect of the head of the fibula. (B, *Right*) Histologic pattern of benign osteochondroma The superficial portion comprises hyaline cartilage, which at a lower level exhibits calcification Observe that the base of the lesion consists of cancellous bone The cartilaginous cap of the tumor is covered by a layer of connective tissue (Photomicrograph ×100)

of the long tubular bones are the most frequent sites of osteocartilaginous exostoses however flat bones are frequently implicated particularly the ribs the scapula the iliac bones and on rare occasions the clavicles and the spinous processes of a vertebra The most common site is the lower end of the femur and the upper end of the tibia In most surveys males are affected more often than females the ratio being 2 to 1 in Lichtenstein s series there was no appreciable difference in the sex incidence As a rule the disorder is observed during childhood or adolescence however, the age range is from 5 to 80 years the highest incidence occurring between 11 and 15 years and approximately 80 per cent of the cases appearing under the age of 21

Clinical Features. In many instances because of the absence of pain and slow growth, the tumor remains obscure and is discovered only accidentally by the roentgenologist By the same token, if the patient is aware of the presence of the tumor, medical advice is not considered as urgent On occasions trauma directs the patient's attention to the neoplasm In other instances the protuberances interfere with normal excursion of muscles and tendons, thereby producing varying degrees of disability of the affected limb or articulation in the vicinity of the tumor Such was the case history of the patient whose knee joint is depicted in Figure 429 left. This individual (female, 16 years of age) was unaware of any abnormalities in the region of the right knee joint. For several months prior to the initial examination the child noted some

stiffness in the back of the knee at the end of the day Later she developed pain in the calf and was aware of an occasional snap on the outer side of the knee joint when walking or running The symptoms were accentuated by activity Finally, some swelling occurred on the outer aspect of the knee the swelling would disappear with rest. Physical examination of the knee in question disclosed a large irregular hard mass in the region of the head of the fibula, over the mass was a distinctly palpable bursa 2½ by 3 cm. distended with fluid Another palpable mass was found on the posteromedial aspect of the supracondylar region. These findings were confirmed at operation

Occasionally the first manifestation of the lesion may be local paralysis resulting from pressure on peripheral nerves The author has recorded a case wherein the first indication of the tumor on the ventral aspect of the scapula in a child 6 years of age was paralysis of the serratus anticus muscle Growth of the lesion occurs during childhood and adolescence when growth ceases is not definitely known however it is generally believed that maturation of the tumor is achieved approximately at the time or several years before skeletal maturation of the individual is attained With increasing age the cartilage cap tends to regress as indicated by irregular areas of calcification within its substance and eventually disappear However in rare instances cartilage rests in a more or less dormant state and is demonstrable in the later decades of life and is capable of reactivated growth

It becomes apparent that quiescent lesions may exist for many years without *clinical manifestations some never give* rise to symptoms As noted previously large tumors in the region of the knee the shoulder or the ankle joint may interfere with normal motion Such neoplasms are firm painless more or less symmetric masses attached to the underlying bone The consistency of the tumor depends upon the amount of cartilaginous tissue present. Soft tissues are freely movable over the lesion. In rare instances a bursa distended with fluid may be attached to the base of the tumor this exostosis bursata" finding is not uncommon in cases of larger osteochondromas. The bursal lining is not unlike synovial membrane the bursal cavity contains mucinous fluid and at times may contain flakes of fibrin, rice bodies and even calcified cartilaginous bodies

Although osteochondromas are essentially benign neoplasms sarcomatous transformation does occur in a small percentage of the cases Some observers record the incidence of this unfavorable sequel as low as 1 to 2 per cent in solitary lesions a higher incidence is noted in multiple lesions Jaffe's series of hereditary multiple exostosis revealed development of chondrosarcoma in 3 of 28 cases or 11 per cent He also pointed *out that the incidence of malignant change* in this same group might be higher because the survey was made at a time when the patients were still young Changes in the nature of the tumor which are ominous signs are pain and increase in size Occasionally *malignant degeneration is initiated* by injury to the implicated region Development of a chondrosarcoma is usually exceedingly slow often many months are required before its evolution is complete It is interesting to note that often they reach appreciable dimensions before their true nature is disclosed

Roentgenographic Features. Roentgenographically osteocartilaginous exostoses exhibit more or less distinctive features The base of the tumor may be broad or it may be a narrow pedicle the former constitutes *the sessile form* and the latter the pedunculated variety (Fig 429) The base comprises normal bone while its periphery is covered by a cartilaginous cap which may exhibit irregular areas of calcification Varying degrees in the size of the cartilaginous covering are discernible in different tumors

The neoplasm may appear as a narrow, regular imperceptible band or massive, irregular, calcifying lesion often referred to as a 'cauliflower mass." Benign lesions exhibit a sharply delineated periphery and a base comprising normal bone which is continuous with the spongiosum of the shaft On the other hand a hazy irregular, ill defined peripheral zone, a granular stippled appearance of the cartilaginous components and irregular areas of bone resorption at the base of the lesion are indicative of malignant transformations

Treatment and Prognosis. Theoretically removal of an osteochondroma should include its periosteal covering this ensures against subsequent reformation of cartilaginous tissue which may give rise to recurrence of the tumor Small tumors producing no symptoms and portraying no manifestations of reactivation require no treatment. It is justifiable to excise tumors which interfere with normal function of the knee joint or press on the surrounding tissues sufficiently to cause pain If excision is attempted the operation should be a definitive one it should be performed through normal osseous tissue beyond the limits of the tumor Large tumors with prominent cartilaginous caps may not be amenable to local excision in such instances resection is the procedure of choice Lesions exhibiting clinical and histologic manifestations of sarcomatous transformations are treated in the manner described for the management of chondrosarcomas.

As recorded previously the most pertinent change pointing to malignant degeneration is an insidious progressive enlargement of the tumor In the light of this information it becomes apparent that known lesions should be checked roentgenographically at regular intervals to uncover any abnormalities in their physical character Malignant changes are usually encountered after the age of 30 making it obvious that periodic evaluation of the tumors is more essential in adults than in children

CHONDROMA

Chondromas are benign tumors derived from cartilage, they are known also as enchondromas and chondromyxomas They are encountered most commonly in the small bones of the hands and the feet however, they occur also in tubular bones, particularly the humerus, the femur and the tibia Males are affected more commonly than females, a ratio of slightly more than 2 to 1 The peak of incidence in all skeletal chondromas is between 20 and 30 years, the age range is between 10 and 70 years

Clinical Features. Quiescent lesions may give rise to no symptoms not infrequently such lesions are uncovered accidentally by the roentgenologist Neoplasms in the region of the knee and the shoulder joints may be responsible for mild pain associated with exertion, it is usually relieved by rest As a rule, disability is insignificant or absent Growing tumors may distend the shaft slowly, producing a uniform or eccentric swelling of the end of a tubular bone Not infrequently the factor responsible for recognition of the lesion is a spontaneous fracture this is particularly true in chondromas implicating the phalanges Also, trivial trauma may produce a fracture. According to some workers the incidence of fracture is 10 per cent of all central chondromas The average duration of symptoms prior to the time when a patient seeks medical aid is approximately 40 5 months

Accentuation of existing symptoms and the presence of a tumor which increases slowly in size comprise highly suspicious clinical evidence of malignant transformation Some observers record malignant alterations in 25 per cent of all chondromas. Malignant changes in tumors situated in long bones are not infrequent on the other hand it is common knowledge that chondromas in the hand or the foot are innocuous development of malignant transformation in these lesions is highly unusual

Roentgenographic Features. In roentgenograms of central chondromas certain



FIG 430 Chondroma of the distal end of the femur Case W S female aged 16 Symptoms of 2 years duration. A block resection of the lesion was done at the time of biopsy which confirmed the roentgenographic diagnosis. No evidence of recurrence 3 years after operation. (*Bottom right*) (Photomicrograph X200) The tissues comprise adult hyaline cartilage the cells of which are round fusiform or stellate in shape. They vary in size. They are more or less uniformly small and contain a single round dark staining nucleus. (*Bottom left*) Specimen removed in block and split in 2 halves. Observe its cartilaginous nature (*Top left*) Roentgenograms reveal a multilocular radiolucent lesion expansile in nature. The cortex of the femur medially and posteriorly is markedly thinned no evidence of new bone formation is discernible. (*Top right*) Roentgenograms taken 6 months post operatively disclose no evidence of recurrence of the lesion The iliac bone grafts inserted into the defect at the time of operation are coalescing

significant and characteristic features are discernible a radiolucent area fusiform or eccentric distention of the shaft of the bone marked thinning of the cortex absence of new bone formation and occasionally perforation of the thin cortex. Roentgenographically *lesions in the long bones resemble* closely bone cysts giant-cell tumors osteolytic osteogenic sarcoma and osteolytic metastatic lesions of carcinoma (Fig 430)

In such cases it is extremely difficult to arrive at a final diagnosis on the clinical and roentgenographic features alone The diagnosis can be established only by histologic examination of the tissue this is most essential when radical treatment is contemplated Irregular lines of calcification may be demonstrable throughout the tumor giving it a multilocular pattern

Histologic Appearance Microscopi

cally the tumor offers no diagnostic problems. The tumor consists of normal adult hyaline cartilage The cells vary in size and are usually round, some may be fusiform or stellate in shape, they tend to be in groups of 2 or 3 Areas of calcification may be found scattered throughout the tumor Strands of connective tissue divide the tumor into facets of varying size, calcification is usually noted in cells close to the connective tissue fibers. The cells lie in lacunae, which are embedded in a hyaline ground appearance The cartilage cells of a benign lesion are uniformly small with single nuclei which are small and round and are dark staining Since the tumor has malignant tendencies, all portions of the neoplasm should be scrutinized before a diagnosis of a benign chondroma is made Some areas of the tumor may disclose some myxomatous material

Treatment. Chondromas are radioresistant tumors, surgical intervention is the treatment of choice Any surgery on these lesions especially when located in the long bones, should be definitive If a biopsy is done, complete removal of the tumor mass by excision or resection should follow In the light of the knowledge that the tumor tends to recur following surgical procedures the aforementioned precautions are most essential Some observers estimate the incidence of recurrences in large bones to be as high as 25 per cent.

It was noted previously that lesions in the small bones of the hands and the feet are definitely benign Extirpation of these tumors invariably produces a cure This is achieved best by meticulous curettage of the tumor then the cavity is cauterized by a saturated solution of zinc chloride followed by thorough irrigation with normal saline solution New bone formation may be enhanced by packing the cavity with bone chips or small bone grafts

Lesions in long bones must be excised completely or resected (Fig 430) Tumors found in the humerus or the fibula lend themselves to this form of surgery If large portions of the shafts are affected, segmental resection followed by bone transplantation gives a satisfactory result. The author has performed this procedure for both chondromas and giant-cell tumors of the upper end of the humerus On occasion the size and the location of the neoplasm make excision or resection impossible In such cases amputation offers the only hope for the patient particularly if there are indications of malignant changes Working on the premise that chondromas of the long bones are potentially malignant some surgeons raise the question as to whether one is justified in waiting for evidence of malignant transformations Thus occasionally amputation is the procedure of choice before sarcomatous alterations manifest themselves

Case Report. Case W S, a female aged 16 was unaware of any disorder of the left knee joint until 2 18-50 when she developed an aching knee.' The child s mother noticed a swelling on the inner side of the knee when she attempted to massage the region with a liniment. Upon further questioning the patient volunteered the statement that for the past 2 years she occasionally experienced a deep-seated ache in the joint following strenuous activity, invariably, the pain was relieved by rest up to the present episode. Examination of the affected limb revealed a bony, hard painless swelling immediately above the internal epicondyle of the femur The skin and the soft tissues were freely movable over the mass no distention of the veins was observed in the overlying skin. All movements of the knee joint were within normal limits the child walked with a normal gait All laboratory studies disclosed normal findings Roentgenographic studies revealed a large eccentric radiolucent area on the inner and posterior aspect of the lower end of the shaft of the femur Calcified trabeculae within the tumor created a multilocular configuration The shaft was expanded on its posterior and inner aspects the cortex was exceedingly thin but no break in its continuity was demonstrable. On the basis of these findings, the roentgenologist made a diagnosis of a tentative giant-cell tumor or chondroma Histologic examination of the material from the tumor obtained by surgical biopsy disclosed the entity of the

neoplasm as being a chondroma (Fig 430) A block resection of the lesion was performed, and the defect was filled with cancellous bone grafts obtained from the iliac crest. The patient has made a complete recovery when seen 3 years following resection of the tumor no evidence of recurrence was demonstrable by roentgenographic study

Benign Chondroblastoma of Bone

Codman was the first to recognize this tumor as a distinct entity and recorded the pertinent characteristics which set it apart from other tumors of cartilaginous derivation In 1931 he collected 9 cases from the Sarcoma Registry the lesions were listed under such diagnoses as osteogenic sarcoma chondrosarcoma and giant-cell tumors. He was of the opinion that they were essentially atypical giant-cell tumors having a predilection for the head of the humerus His enthusiasm stimulated new interest in cartilaginous tumors soon it became apparent that similar lesions arise in the epiphyseal regions of other long bones particularly in the lower end of the femur and the upper and the lower ends of the tibia.

Origin. Although there was considerable controversy relative to the origin of this tumor when first introduced by Codman now it is generally accepted that the lesion is in no way related to the giant-cell tumors that it has a cartilaginous origin and is a benign innocuous lesion Codman put forth the premise that it was an atypical giant-cell tumor arising in the region of the tuberosities of the head of the humerus at an age before the ossification of the epiphyseal cartilages was completed and that the "peculiar epitheloid cells which merge into a low-grade type of cartilage cell" found in the neoplasm arose from the epiphyseal cartilage He was supported by Willis who reported a case whose histologic structure conformed to the views of Codman

Other observers are in complete disagreement with this theory of origin Geschickter believes the lesions arise from the metaphyseal side of the epiphyseal line and that the proliferating tissue is of cartilage derivation and not composed of giant cells he designated the lesion "chondroblastic tumors, benign and malignant On the other hand Coley reports that he knows of no verified instance of metastasis of the tumor and that a cure was effected in all his cases by conservative measures. The author s experience supports the observation of Coley 6 cases of chondroblastoma have been treated by excision and curettage in all no evidence of recurrence or metastasis has occurred The observations of Jaffe and Lichtenstein support those of Coley they are convinced that the lesions have a cartilaginous origin and are benign they designate them "benign chondroblastoma of bone

Clinical Features. Chondroblastomas are encountered between the ages of 12 and 24 at a time when the epiphyseal cartilages are not as yet obliterated by ossification Codman s cases fell into this age group Males are affected more frequently than females 80 per cent of the cases are observed in males As recorded previously tuberosities of the humerus the lower end of the femur and the upper and the lower ends of the tibia are the sites of predilection

Characteristic of the tumor is its mild insidious onset Its chronicity is demonstrated by the long interval between the onset of the disease and the treatment it ranges from 5 to 36 months The only significance that can be allocated to trauma is its role in making the patient cognizant of an existing lesion. At first there are pain and stiffness in the region of the knee joint varying degrees of disability may be present Later a definite tumefaction may be demonstrable Although the mass is not tender to superficial palpation firm pressure over the affected region may elicit tenderness Limping is present constantly in older lesions involving weight bearing bones particularly when they occur in the region of the knee or the ankle Varying degrees of atrophy of the quadriceps muscles are observed in cases implicating the

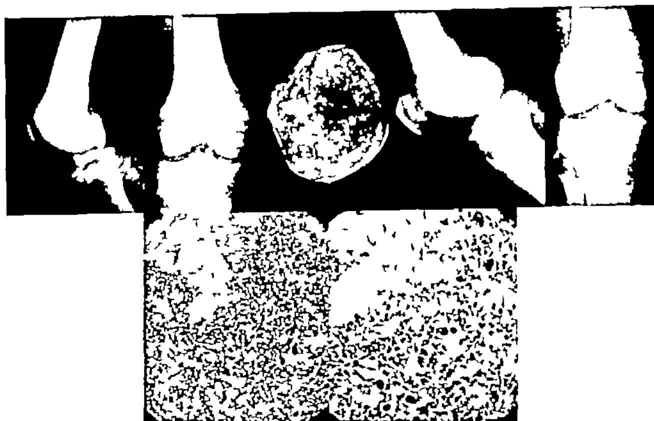


Fig. 431 (*Top, left*) Case E P chondroblastoma of the distal end of the femur It does not implicate the articular cartilage. It is multilocular and exhibits a flocculent appearance. (*Top, center*) Specimen (sectioned) obtained after a block resection of the lesion was performed Observe that it is well demarcated from the surrounding bone except at one area (upper right) (*Top right*) Roentgenograms showing complete resection of the tumor (*Bottom*) (Photomicrographs ×100, ×200) Benign chondroblastoma Observe the stellate character of the cells and the myxomatous stroma also the fibroblastic proliferation and the numerous chondroblasts numerous giant cells are scattered throughout the field.

bones of the knee joint, on occasion an effusion is discernible in the joint. The benign nature of the neoplasm is evidenced by the clinical observation that conservative management results in a permanent cure

Roentgenographic Features It is interesting to note that chondroblastomas usually occupy an eccentric position in the involved bone (Fig 431) As a rule, the lesion does not extend beyond the epiphyseal plate to involve the articular cartilage Only one such case is on record reported by Jaffe wherein the neoplasm implicated the articular cartilage of the head of the humerus The tumors are consistently small and are sharply demarcated from the surrounding normal bone by a zone of increased density they present a "fluffy cotton wool look" Scattered throughout the tumor irregular areas of calcification are noted frequently, producing a multilocular, flocculent appearance Trabeculations such as those seen in giant-cell tumors are absent Occasionally new bone formation is demonstrable on the outer surface of the cortex of the shaft in the vicinity of the tumor this periosteal response is more evident in older lesions

Microscopic Features. Essentially, the cytologic pattern comprises masses of immature cartilage cells embedded in a cartilaginous matrix. The pattern varies in different tumors and even in different areas of the same specimen In the early stages of development the tumor is more cellular than in the later stages and consists of compact

ovoid polyhedral cells varying in size the nucleus is relatively large, on occasion more than one nucleus is present A variable number of multinuclear or giant cells are scattered throughout the field they appear to have no specific part in the cytologic scheme of the tumor Occasionally one observes areas of calcification and ossification in the matrix, dispersed throughout the cellular elements In addition, focal areas of necrosis may be demonstrable these stimulate a separative process whereby connective tissue is formed As pointed out by Lichtenstein this connective tissue may assume the form of collagenous plaques resembling chondroid or osteoid matrix in some areas the latter may progress to osseous transformation

Diagnosis. The neoplasms most likely to be mistaken for chondroblastoma are osteogenic sarcoma chondroblastomic sarcoma giant-cell tumor and chondrosarcoma. Features which set it apart from other lesions are the location of the tumor the benign course and the long duration of symptoms and its cytologic pattern

Treatment and Prognosis. The treatment of choice is thorough curettage of the lesion or block excision of the mass where possible the resulting defect may be filled with cancellous bone chips to enhance obliteration of the cavity Intensive irradiation is contraindicated because of the doubtful effect it has on the tumor and the severe soft tissue contraction that may occur Abolition of a limb as a form of treatment is very seldom justified The simple surgical measures outlined above eradicate the tumor and restore good function at the knee joint the same is true of lesions in the vicinity of other joints In all the cases reported by Codman Jaffe and Coley conservative management resulted in a permanent cure

Case Report Case E P a male aged 24 injured his right knee at work approximately 3 weeks prior to his admission (3 20-51) to the hospital The knee became swollen and painful on motion After several days of r the swelling and the acute tenderness disa peared gradually but he became aware of hard "lump like a golf ball on the inr aspect of the knee joint Although the pa was not severe it was constant and he notic no diminution of the size of the tumor

Physical examination of the affected regi revealed slight swelling of the knee joint sulting from a moderate effusion in the jo cavity A round, bony hard mass was palpal over the medial epicondyle of the femur was not particularly painful except when fi pressure was made over it. Laboratory inves gations disclosed no abnormalities. Roentger graphic study showed a discrete round tum confined to the upper and inner portion of t distal femoral epiphysis part of the tum had involved a portion of the metaphysis. occupied an eccentric position so that it e tended beyond the limits of the cortex It p sented a woolly mottled appearance (F 431) Histologic findings in the material c tained from the lesion were consistent wi chondroblastoma of bone

A block excision of the tumor mass was pe formed, and the base of the defect w curetted thoroughly Full function was r stored to the knee joint as yet no evidence recurrence is demonstrable

Giant-Cell Tumor

Introduction. It is now commonly co ceded that giant-cell tumor is a beni primary bone neoplasm primarily affecti the ends of the shafts of long bones Up the time that the benignity of this lesi was definitely established many limbs we sacrificed needlessly under the erroneo diagnosis of osteogenic sarcoma. Such wor ers as Cooper Paget Mlater Gro Stewart Coley Bloodgood and others co tributed much valuable information relati to the true nature of this disorder and them goes the credit for recognizing an emphasizing its benign characteristics though this is true of most giant-cell tumo it is now generally recognized that on occ sion giant-cell tumors undergo maligna transformations and may metastasize to t lungs. Also such tumors have been encou tered before any form of therapy was insti tuted However the majority of malignant

giant-cell tumors have been observed following some form of therapy, usually irradiation

Age and Sex Analysis of the numerous series of giant-cell tumors reveals that the highest incidence is in the third decade, they are rarely found in children or in individuals past middle life. According to Geschickter and Copeland, 40 per cent of all giant-cell tumors occur between the ages of 20 and 30 years. Coley records 48 out of 124 cases occurring between 21 and 30, and 78 in 124 being between the ages of 21 and 40 years. There is no predilection as to sex males and females are affected about equally

Site. The most common sites in order of frequency are the distal end of the femur the proximal end of the tibia, the distal end of the radius and the upper end of the humerus the first three locations account for at least 60 per cent of all giant-cell tumors Coley reports that 14 cases implicating the patella have been recorded

One of the distinguishing features of giant-cell tumors is its location in the cancellous portion of the tubular bones also, it appears primarily as a solitary lesion in the aforementioned sites Nevertheless, they have been observed in all the bones of the body including the skull Usually, in the early stages of development the tumor occupies an eccentric position in the subcortical portion of the epiphysis later by gradual expansion and destruction of the less-resistant cancellous bone it occupies a more central position On occasion the tumors are completely eccentric appearing to take origin beneath the periosteum some observers have designated such tumors subperiosteal giant-cell tumors. Subperiosteal lesions resembling giant-cell tumors have been reported as arising from the shaft of long bones at a distance from the epiphyseal region Some observers believe that these are true giant-cell tumors identical with those found in the epiphyseal regions, other workers are of the opinion that they comprise a distinct and separate entity being sequelae of subperiosteal hematoma Lichtenstein regards this tumor as a distinct entity unrelated to giant-cell tumors arising in the epiphyseal regions of tubular bones and has designated it aneurysmal bone cyst

Etiology The origin of giant-cell tumors remains a controversial subject numerous theories have been advanced Through the efforts of Stewart (1922) the theory of hemorrhagic osteomyelitis conceived by Barrie has been discarded There are still some supporters of the neoplastic theory some of whom postulate that the tumor arises from marrow cells, others are of the opinion that it originates from and consists of "bone formative cells" (Willis) which possess osteoclastic characteristics

The most popular is the traumatic theory Codman set forth the premise that rupture of a nutrient artery which fails to clot was the origin of all giant-cell tumors. From this nidus arises a pulsating mass of tissue which produces resorption of the adjacent cancellous bone trabeculae The mass tends to progress centrally because cancellous bone is less resistant than cortical bone Extension of the mass into the shaft is prevented by the pulsating bone marrow

Geschickter and Copeland maintain that trauma following subperiosteal hemorrhage interrupts normal blood supply to the cortex of the adjacent bone. This results in increased osteoclastic activity in the subcortical region of the traumatized cortex and finally by hyperplasia of osteoclasts, a tissue designated giant-cell tumor is formed

On the other hand Jaffee Portis and Lichtenstein are convinced that giant-cell tumors are distinctive primary bone tumors originating from the non-bone-forming supporting connective tissue of the marrow They emphasized that the tumor comprises a vascular network of spindle-shaped or ovoid stromal cells throughout which are interspersed multinuclear cells, this feature is an integral part of the cytologic pattern Jaffe pointed out that the so-called giant cell variants are in no way related, clini

cally or anatomically, to the true giant-cell tumor the only similarity is the benignity of the lesions and the favorable prognosis.

Macroscopic Pathology Examination of the gross specimens reveals the subcortical origin of the tumor Usually they occupy an eccentric position and tend to invade the bone centrally, while the more resistant cortical bone acts as an effective barrier to peripheral expansion of the tumor As a rule the affected portion of the bone is expanded and the tumor involves the epiphyseal region and the adjacent metaphysis. In more advanced lesions pronounced expansion of the bone and thinning of the cortical shell occurs the cortical layer of bone may be perforated in several places When this occurs the periosteum and a thin layer of newly formed bone replacing the original cortex, tends to delimit the tumor mass even this last barrier may be overcome by the growing tumor causing invasion of the surrounding soft tissues Once the osteoperiosteal cuff is perforated aggressive tumors may extend along intermuscular septa even cross the joint line to invade other bones. However only rarely does the tumor invade a joint the articular cartilage resists invasion. It is not uncommon to observe in advanced lesions the cartilage still intact sitting like a cap on a mass of tumor tissue while the bony elements are totally destroyed Extension of the tumor shaftward does not progress any appreciable distance beyond the metaphyseal region yet only a thin fibrous or osseous zone may separate it from marrow As recorded previously Codman believed that the pulsating bone marrow tends to limit the advance of the tumor

Generally the tissue is very cellular varying in color and consistency in different tumors As a rule it is friable disintegrates readily and bleeds freely it ranges in color from red to black on occasion it is firm puttylike and of a grayish white color Interspersed throughout the tumor mass fibrous trabeculae—some fine others coarse—are often encountered they appear to extend into the substance of the tumor from its periphery Not infrequently, marked generalized oozing and even large spurring vessels are encountered during operation, indicating the great vascularity of the tumor At times the hemorrhage may be difficult to control Other tumors may be avascular permitting curettage without difficulty The characteristics mentioned above may be altered by secondary changes within the tumor Soft areas, colored a bright red or a bluish red are indications of hemorrhage yellowish or orange isolated portions of the tumor point to necrosis of the tissue. In advanced lesions with marked secondary alterations the tumors take on a cystic appearance

Microscopic Pathology As in the gross specimens the histologic picture varies in different tumors or in different areas of the same tumor, depending upon the stage of development of the neoplasm and the degree and the intensity of the secondary changes within it In tumors exhibiting no (or only minimal) secondary changes, the tissue consists of a characteristic stroma made up of mononuclear spindle or ovoid cells varying numbers of multinuclear giant cells and small amounts of intercellular collagenous substance consisting of fine fibers The cytologic pattern described above is most applicable to regions of the tumor which disclose few or no secondary alterations.

The ratio of spindle to ovoid cells varies in different tumors These cells contain a single round or elongated nucleus which occupies a considerable portion of the cell In addition each nucleus exhibits a well defined central nucleolus and a moderate amount of evenly distributed chromatin material Usually the ovoid cells are found in greater numbers than the spindle cells The outline of the cytoplasm of the stromal cells may be indistinct and exhibit delicate cytoplasmic processes As recorded previously Jaffe is of the opinion that the most plausible origin of stromal cells is from mesen

chymal supporting connective tissue of the marrow Some stromal cells disclose mitotic division

Irregularly dispersed throughout the stroma are the multinucleated giant cells measuring from 30 to 100 or more microns The number of these cells per field varies generally, the number demonstrable in the low power field ranges from 10 to 35 cells The nuclei of the giant cells vary in number from 15 to 100 or more per cell they tend to occupy a central position in the cell It is interesting to note the remarkable similarity of the nuclei of the giant cells to the nuclei of the ovoid stromal cells. This similarity forms the basis of the premise supported by some observers that the giant cells are formed by fusion of stromal cells

In uncomplicated giant-cell tumors collagen fibers are not abundant The collagenous material is more plentiful when the stromal cells exhibit a loosely arranged pattern than in a compact arrangement of the stromal cells Vascularity of the tumor tissue is also a variable feature the vascular spaces are thin walled, composed of flattened endothelial cells. Not infrequently tumor cells are demonstrable in close relation with the walls of the blood channels Areas of hemorrhage may be discernible throughout the tumor tissue

Credit goes to Jaffe for emphasizing the alterations that occur in the stromal cells when malignant transformations are occurring in a giant-cell tumor He is of the opinion that a typical, uncomplicated giant cell tumor exhibits a characteristic stromal pattern Changes in this pattern indicate

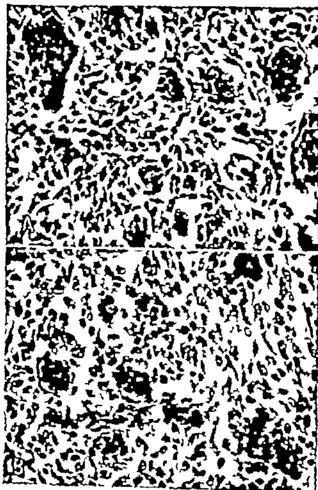


FIG 432 (A) (*Top*) Tissue from a giant-cell tumor of Grade I that occupied the head and the neck of a humerus in a woman of 30 (×275) There was no preoperative irradiation of this tumor Note the abundance of large giant cells and the predominantly spindle-shaped and not closely compacted stromal cells between them The stromal cells presented few mitoses and no evidences of atypism Altogether, this histologic picture represents what can definitely be called a "benign' giant-cell tumor, curettage and postoperative irradiation of the lesion were followed within a year by substantial repair of the affected area

(*Bottom*) Tissue from a giant-cell tumor still properly classifiable as belonging to Grade I but no longer so clearly 'benign as the tumor of above (×245) The lesion occupied the head and the neck of a femur in a woman of 22 There was no preoperative irradiation of the tumor Note that the giant cells are rather abundant between the stromal cells and that the latter are abundant but not closely compacted The stromal cells do not show appreciable atypism but here and there some of them have large nuclei and an occasional one even has two nuclei In this case, postoperative irradiation was not followed by prompt clinical improvement Eventually we lost sight of this patient because she left the country (Jaffe, H. L., et al Arch. Path. 30 993)

the aggressiveness of the tumor, certain features pointing to a frankly *malignant* giant cell tumor He describes three grades of aggressiveness

Grade I is the least aggressive In this tumor there is a loose arrangement of the cells with no appreciable atypism of the stromal cells. Grade II is more aggressive Tumors in this category tend to recur and *may even assume characteristics of Grade* III The stroma cells are in greater abundance than in Grade I forming a compact stromal pattern and disclosing definite manifestations of atypism Grade III is characterized by a dense compact stroma with an irregular whorled atypism Tumors in this group are malignant lesions and usually metastasize to the lungs. Generally, they represent malignant transformations occurring in Grades I and II but occasionally begin as Grade III neoplasms (Fig 432)

Clinical Features. A survey of the many reported series of giant-cell tumors reveals *that the highest incidence occurs in the* third decennium they are exceedingly rare before the age of 20 nevertheless, a few cases have been reported The author has observed a giant-cell tumor in an adolescent 15 years of age the tumor occurred

Fig 432 (B) (*Top*) Tissue from a giant-cell tumor already classified as belonging to Grade II (×285) The lesion occupied the lower end of a femur in a man of 36 There was no preoperative irradiation of the tumor Note the compaction of the stromal cells and the presence of multiple nuclei in some of them. More of the stromal cells showed mitoses than show them in a tumor of Grade I Despite postoperative irradiation the lesion progressed, and 2¼ years later the histologic picture had changed completely the lesion having become frankly malignant.



(*Bottom*) Tissue from a giant-cell tumor of Grade II that occupied the lower end of a femur in a woman aged 23 (×90) The tissue shown represents material obtained from the lesion through curettement some time after a thorough course of radiation therapy had failed to control its progression Subsequently the lesion became infected and fungated and the limb was ablated. Note that the field illustrated contains numerous densely compacted spindle-shaped stromal cells but that hyalinization of the stroma which would indicate an irradiation effect, is absent Note also that hardly any giant cells are to be seen in the photomicrograph In other fields of the tumor however they were very numerous and the histologic architecture altogether so characteristic that there could be no doubt that one was dealing with a giant-cell tumor in spite of the concomitant presence of more ominous-looking areas like the one shown (Jaffe H L et al Arch Path 30 993)

in the upper end of the humerus Frequently, the patient's attention is focused on the affected region by some form of trauma Pain of varying intensity is the cardinal symptom It may be intermittent, relieved by rest and accentuated by activity Some limitation of motion and dysfunction of the knee joint are usually discernible As the tumor progresses the pain becomes constant and more severe It may be more pronounced at night, interfering with the patient s sleep At times slight swelling and tenderness on palpation may be the factors that make the patient aware of the pathologic process. In most instances, because of its insidious nature, the tumor attains an appreciable size before its entity is uncovered One case in the author s files implicating the upper end of the tibia had progressed to such a degree that the involved region was at least twice its natural size In fact, medical aid was requested only after a pathologic fracture had occurred The amount of swelling in the region of the knee joint varies occasionally, swelling of the limb distal to the lesion is demonstrable Expansion of the shaft and thinning of the cortex may result in a spontaneous fracture when this occurs, all symptoms become more pronounced and functional impairment of the extremity is increased

Physical Findings. As indicated the tumor grows insidiously, hence, no physical evidence may be evident during the early stages However as a rule varying degrees of impairment of the function of the knee joint are manifested early and its intensity parallels the growth of the neoplasm The topographic anatomy of the knee joint permits early detection of any swelling Palpation may reveal an eccentric tumefaction of the femur or the tibia particularly in more advanced cases Pressure over the affected region invariably elicits tenderness

As the tumor progresses the above signs and symptoms are accentuated The affected region appears to be fuller and more promi

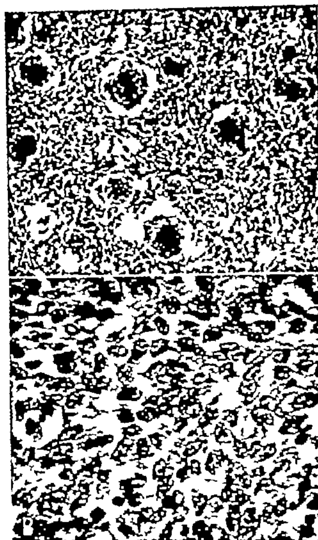


Fig 432 (C) (*Top*) Tissue from a giant-cell tumor of Grade II which occupied the lower end of a femur of a man, aged 44 (×150) Radiation was not given preoperatively but was used after thorough curettage. Nevertheless, there was a recurrence, associated with infection and fungation, necessitating ablation of the limb about 1½ years later The field illustrated is from the tissue originally curetted Note, between the giant cells, the densely compacted stromal cells in a somewhat irregular whorled arrangement. In the field illustrated, these cells when studied in detail did not present much atypism, but in other fields (*bottom*) they did This shows the necessity for studying the details of the stromal cells from many areas and gauging the prognosis of the lesion by its most ominous-looking parts

(*Bottom*) A stromal cell field showing atypism from the same tumor as above (×550) Note that several of the cells contain two or more nuclei that the nuclei in general are large and that many of them show hyperchromatism. (Jaffe, H L., et al. Arch Path 30 993)

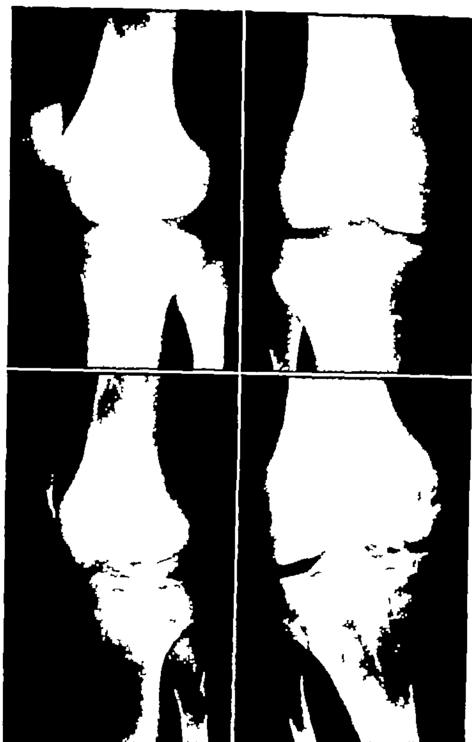


FIG 433 (*Top*) Giant-cell tumor of the inner femoral condyle Case L. C male aged 31 Observe the eccentric position of the lesion the inner cortex of the femur is markedly thinned but the articular surface is not involved (*Bottom*) This patient was treated elsewhere by irradiation the joint changes which ensued are depicted These roentgenograms were taken 5 years later Note the joint changes which have occurred The patient now has constant pain and marked limitation of motion. Roentgenographically there is some evidence of recurrence of the lesion in the epicondylar region This was proved by biopsy Eventually this limb was amputated

nent than the normal side Some effusion may be demonstrable in the articular cavity of the knee joint. Motion of the joint is definitely impaired and guarded by protective muscle spasm, the knee may be held constantly in slight flexion One patient exhibited a fixed flexion contraction of 30° he walked on the ball of his foot with a decided limp Pressure over the expanded position of the affected bone manifests considerable tenderness. In all instances the skin is freely movable over the bony prominences of the knee joint and over the implicated bone and exhibits no significant diagnostic features In very vascular and rapidly growing neoplasms a sense of pulsation in the tumor may be elicited this is an exceedingly rare finding The rarity of pulsating giant-cell tumors is reflected in the paucity of this lesion in the literature, up to 1947 only 7 such tumors had been recorded This feature is more commonly associated with thyroid or renal metastasis to bone

Roentgenographic Features. It must be emphasized that the roentgenographic features of a giant-cell tumor are extremely variable The most pertinent findings are an eccentrically placed radiolucent area in the ends of the bones, thinning and expansion of the cortical bone and the age of the patient (usually the third decade) (Fig 433) Also of significance is the absence of periosteal bone formation over the expanded cortex. Although the aforementioned findings are subjective of a giant-cell tumor, clinical experience discloses that they are



Fig 434 Recurrent giant-cell tumor with malignant transformation. Case S W, male, aged 42 A biopsy of the lower end of the femur was done a diagnosis of giant-cell tumor was made by histologic examination. Irradiation was given elsewhere 3 years later the lesion continued to grow and presented the features depicted herein Note the multilocular pattern following irradiation. A biopsy at this time revealed sarcomatous transformation of the tumor Adequate treatment was not given at this time (the limb should have been amputated), 1 year later the patient died of pulmonary metastasis

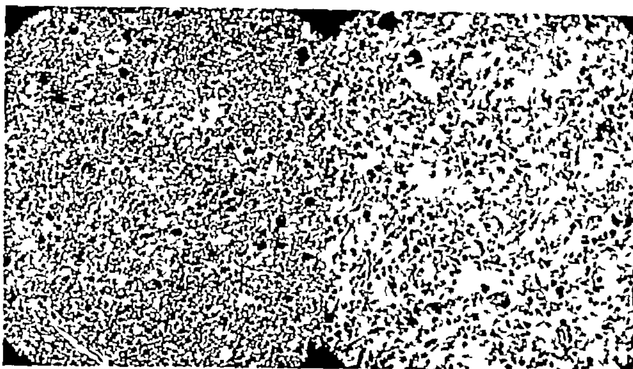


Fig 435 Tissue obtained from a benign giant-cell tumor of the upper end of the tibia in a male 22 years old. Observe the cytologic pattern of the stroma the stroma consists of numerous mononuclear ovoid and spindle cells and small amounts of intercellular collagenous substance which exhibits fine fibrils. Many multinucleated giant cells of varying size and with varying numbers of nuclei are discernible (Photomicrographs left ×100 right ×200)

not infallible and the ultimate diagnosis must be made by histologic investigation of material obtained from the affected region Simple radiolucent areas in the epiphyseal region of tubular bones possessing roentgenographic features suggestive of a giant cell tumor may also be produced by lesions such as osteolytic metastatic tumors and cortical osteogenic sarcomas This again substantiates the importance of histologic study before a final diagnosis is possible (Fig 435)

In the early stages only an eccentrically placed area of rarefaction may be observed Later with resorption of the cancellous bone the lesion occupies a more central position (Fig 433 top) Fine or coarse trabeculae may traverse the tumor giving it a bubblelike pattern the affected areas of the femur the tibia or the fibula expand the cortical shell becomes thin and may even reveal evidence of perforation by a break in its continuity In untreated cases this multilocular configuration is relatively rare, and when present other lesions than giant-cell tumors must be seriously considered (Fig 434) Notably among these are nonosteogenic fibroma enchondroma hemangioma and fibrous dysplasia. Generally the neoplasm does not extend far beyond the limits of the metaphysis into the shaft Total destruction of all the bony elements may occur in the implicated region of the affected bone the limits of the tumor being maintained by a barely perceptible thin bony shell and a thickened periosteal tube Occasionally only the periosteal covering remains in certain areas around the tumor As indicated previously the cartilage resists invasion and may become calcified new bone may form on its surface opposite the tumor tissue so that in roentgenograms it is discernible as a thin smooth line of increased density At no time is roentgenographic evidence of peri

osteal reaction present, resulting in new bone formation, also no soft tissue swelling is demonstrable except when the lesion has ruptured through the limiting periosteal membrane and implicates the surrounding soft tissues such a complication is rare In the event of fracture, displacement of the fragments is not pronounced No evidence of repair is evident clinically or roentgenographically

Diagnosis. The age of the patient and the location of the tumor are the two most significant factors in establishing a diagnosis of giant-cell tumors Nevertheless, there are several entities, neoplastic and non neoplastic, which may resemble closely the characteristics of these tumors, both clinically and roentgenographically It becomes apparent that before any therapeutic modality is instituted, the diagnosis of giant-cell tumor should be confirmed by histologic examination Osseous lesions which are more apt to be confused with giant-cell tumors are (1) bone cyst, (2) malignant giant-cell tumor, (3) medullary osteogenic sarcoma (4) benign chondroblastoma of bone (5) hyperparathyroidism, (6) metastatic carcinoma, (7) myeloma and (8) fibrous dysplasia.

Bone Cyst If one is not aware of the subtleties in diagnosis of a giant-cell tumor, this lesion may be interpreted fallaciously as a bone cyst in some instances Bone cysts possess certain characteristics which closely resemble giant-cell tumors. In the region of the knee joint they usually are situated in the upper ends of the tibia and the fibula or in the lower end of the femur in close proximity to the epiphyseal cartilages they exhibit expansive tendencies (the transverse dimensions of the shaft increase and the cortical shell may become so thin that fracture ensues) their cytologic pattern may bear resemblance to that of giant-cell tumors and finally to their *benignity*

The features that set giant tumors apart from bone cysts are (1) their occurrence in an older age group after epiphyseal ossification is complete, (2) giant-cell tumors occupy an eccentric position in the region of the epiphysis on the epiphyseal side of the metaphysis, (3) bone cysts occur in younger individuals in whom the epiphysial line is still open, the lesion arises on the diaphysial side of the metaphysis

Although both lesions are considered as benign the clinical course of bone cysts differs from that of giant-cell tumors in their mildness It is common knowledge that many bone cysts cause no symptoms and are uncovered only by chance or when a fracture occurs. Fracture through a bone cyst initiates a reparative process which, on occasions, may not only heal the fracture but also obliterate the cyst Reparative processes of this nature never are encountered in pathologic fractures occurring in giant-cell tumors.

Occasionally the cytologic patterns of the two entities may bear such a close resemblance to one another that of necessity the final diagnosis must depend upon the clinical course of the lesions, the age of the patient, the location of the lesion in reference to the epiphyseal line and the roentgenographic features.

Malignant Giant-Cell Tumors Clinical and roentgenographic features of a malignant giant tumor are not sufficient to establish a positive diagnosis The true nature of this lesion can be detected only by microscopic examination which reveals the sarcomatous stroma of the tumor *On the* other hand giant-cell tumors which undergo malignant transformation *following irradiation* surgery, or both manifest their true character by recurrence of symptoms at varying periods following the initial therapeutic *modalities (Fig 434)* The diagnosis is substantiated by histologic study of the material constituting the tumor It is obvious, of course, that clinical evidence of pulmonary metastasis following treatment of a supposedly benign lesion confirms the ma*lignant* nature of the lesion

Benign Chondroblastoma of Bone. On

occasion this lesion may be confused with a giant-cell tumor When Codman first described it in 1931 he was of the opinion that it *occurred solely in the greater tuberosity* of the head of the humerus Now it is known to occur in the ends of the tubular bones It is encountered in a younger age group than giant-cell tumors before the ossification of the epiphyseal plate and does not progress beyond the epiphyseal cartilage to involve the articular cartilage The tumors are consistently small and sharply delineated from the surrounding normal bone by an area of increased density As a rule *no trabeculations are discernible in the tumor* which has a "fluffy cotton wool appearance in the roentgenogram Their clinical course is by far more benign than that of giant cell tumors and microscopic examination identifies them readily and discloses their cartilaginous derivation.

HYPERPARATHYROIDISM Osseous lesions associated with hyperparathyroidism are non neoplastic and are usually multiple involving many or all of the bones of the body *The lesions are more or less diffuse* chiefly implicating the shaft of the bones However it is not unusual to encounter localized radiolucent areas in the ends of bones which resemble giant-cell tumors Moreover microscopic examination may fail to differentiate the lesions from genuine giant-cell tumors because of the close similarity in the histologic sections It becomes apparent that these difficulties in diagnosis may deter the correct treatment in the individual case or may *be responsible for instituting* wrong therapy

Study of the blood constituents establishes the diagnosis Normal serum levels of calcium phosphorus and pho[illegible] are present in giant-cell tumors [illegible] serum calcium and the phosph[illegible] vated and the phosphorus is [illegible] hyperparathyroidism

ticularly when the lesions present an expanded appearance and are traversed by trabeculae giving the lesion a multilocular pattern *This lesion is most often misdiagnosed* as one of the so-called variants of giant-cell tumors—subperiosteal giant-cell tumor The inconspicuous clinical course and its chronicity distinguish it from giant cell tumors However should spontaneous fracture occur identification of the lesion on the clinical and roentgenographic features alone becomes more difficult and involved Final diagnosis must be made by histologic examination

OSTEOGENIC SARCOMA. It is not too unusual for a giant-cell tumor to be overdiagnosed as an osteogenic sarcoma the dangers of this mistake are obvious. Moreover medullary or central osteogenic sarcomas may be underdiagnosed as giant-cell tumors This osteogenic sarcoma may arise in the distal end of the femur and the upper ends of the tibia and the fibula and in the early stages of development it may pursue a clinical course not unlike that of giant-cell tumors *Roentgenographically a radiolucent* lesion is demonstrable in the epiphyseal regions of the femur the tibia and the fibula consistent with an osteolytic process no new bone formation is discernible Hence even by roentgenographic study the sarcomatous lesion may not differ essentially from giant-cell tumor Histologic examination is the only diagnostic aid that will establish the identity of the tumor

METASTATIC CARCINOMA. Occasionally *isolated metastatic lesions of the bones* in the region of the knee joint may occur the upper end of the humerus is another site of predilection [illegible] tumors renal and thyroid [illegible] lesions most likely to produce [illegible] solitary lesions One case of hy[illegible] treated by the author prov[illegible] lesion in the upper end of [illegible] resection of the [illegible]

new bone formation Aids in establishing the diagnosis are the patient's age (such lesions usually occur after the third decade), the general physical status, the demonstration of a primary lesion and microscopic examination of the tissue.

In the same vein, other osseous lesions that must be considered in the differential diagnosis are central chondroma and such tumors of the marrow cells as plasma-cell myeloma, myelocytoma, lymphocytoma and erythroblastoma.

Treatment. As yet there is no unanimity as to the mode of treatment that produces the highest incidences of cures This stems from two causes (1) lack of well-controlled large series of cases treated by surgery or irradiation and followed for a sufficiently long period of time (5 to 10 years) and (2) failure to correlate the various modalities of therapy with the malignant potentialities of the tumor as discernible by its cytologic pattern. As pointed out by Lichtenstein it is difficult to evaluate the efficacy of any method unless such a study is undertaken and carried out to a successful conclusion It is very probable that giant-cell tumors exhibiting genuine benign cytologic features may respond to surgery as well as irradiation while more aggressive tumors may tend to recur or even become frankly malignant metastasizing to the lungs in spite of the therapeutic measures employed Moreover there is a sad need of standardization of roentgen therapy no two radiotherapists employ the same formula

Essentially there are two methods of treatment for giant-cell tumors—irradiation and surgery Some investigators contend that treatment by roentgen rays causes less impairment of function and is followed by few recurrences On the other hand exponents of the surgical management maintain that this method is followed by shorter periods of disability that fracture is a common sequel of irradiation and that sarcomatous changes may appear in irradiated bone Coley notes that 25 per cent of the cases of giant-cell tumors of long bones treated by irradiation sustained pathologic fractures.

In this country at least, there is a general trend to favor the surgical approach to this problem and employ roentgen rays only in tumors inaccessible to surgery or in lesions which have progressed to such a stage that complete extirpation of the tumor tissue is impossible. Irradiation is used also in lesions that have caused total destruction of the joint and when the tumor tissue has invaded the joint cavity The surgical procedures employed are curettage resection and amputation.

Curettage Small giant-cell tumors or tumors which are still at a distance from the articular surfaces in the lower end of the femur and the upper end of the tibia are especially amenable to curettage, while those in the upper end of the fibula lend themselves nicely to resection.

Advanced lesions in the femur and the tibia implicating the articular cartilage are less suited for curettage because incongruity of the weight bearing surfaces is inevitable and severe impairment of function may ensue This is not true in lesions of the upper end of the humerus

Surgical approaches to giant-cell tumors in the region of the knee, as elsewhere in the body should provide adequate visualization of all aspects of the affected region This is essential to a correct evaluation of the extent of the lesion and for gaining access to all tumor tissue.

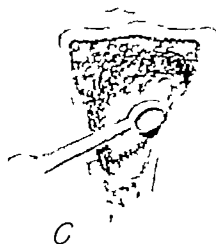
Tumors situated in the condyles of the femur may be exposed by vertical skin incision from 5 to 6 inches in length made directly on the respective condyles for exposure of lesions in the condyles of the tibia hockeystick-shaped incisions may be employed the vertical limb of the incisions parallels the margins of the patellar tendon while the horizontal limb runs immediately below the superior margins of the tibial condyles (Fig 436) After complete hemastasis of the skin and the subcutaneous tissue the













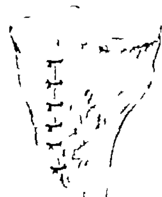


FIG 436 (A B and C) Technic of curettage of giant-cell tumor of the upper end of the tibia. (D and E) Packing the defect with cancellous bone chips and bone struts and closure of the defect.

skin edges are fastened to towels by skin clips to protect the wound edges from exposure and contamination In approaches for lesions implicating the femoral condyles, the next step is division of the fascia of the leg in line with the skin incision Then the muscles are split along the line of their fibers by separation of the muscle masses, the periosteum of the femur comes into view At this point emphasis should be placed on care and gentleness to be exer cised while obtaining the desired exposure All soft tissues are covered and packed away from the involved bone by large hot sponges. By so doing, contamination of the tissues by tumor material will be averted as it is being removed from the bone cavity

Generally, the periosteal tube around the affected area is intact it is divided longi tudinally down to the bone and reflected to either side. The thin cortical shell is per forated readily with a bone gauge, and the opening is enlarged by rongeurs until all areas within the cavity are accessible All tumor material is removed with a large curet taking care to avoid spilling An angular curet facilitates its removal from the roof of the cavity Curettage is con tinued until normal healthy bone is reached Then the cavity is flushed thoroughly with normal saline solution and is sucked dry This is repeated several times until all loose fragments of tissue are removed Next the cavity is swabbed with a solution of satu rated zinc chloride and then flushed again with normal saline solution Finally the cavity is packed tightly with a hot gauze sponge which is left in situ while bone chips are being prepared to fill the defect

Small cavities with an intact cortical hell are packed with small bone chips obtained from the iliac crest bank bone may also be used for this purpose Not infre quently the defect is large after curettage or the cavity collapses after its contents have been removed as a result of dissolu tion of the cortical shell In these instances it is advantageous to use 4 or 5 long strips of bone in the cavity as struts, they are placed parallel with the long axis of the shaft of the femur To enhance osteogenesis the spaces between the struts are packed with autogenous cancellous bone chips Rib bones split in halves make admirable bone struts for this purpose. (A supply of rib bone is always available in the bone bank)

The periosteum is closed over the defect with interrupted cotton sutures, and the muscle is allowed to fall into its natural position its edges are also approximated with interrupted nonabsorbable sutures. Ac curate coaption of the fascia and the skin is achieved in a similar fashion

If the defect is small, no external fixation is necessary An elastic bandage applied over a layer of cotton padding and making uniform pressure provides sufficient splint ing In these cases early joint function with out weight-bearing is encouraged After the acute postoperative reaction has subsided, partial and later full weight bearing is per mitted. In the event that a pathologic frac ture was sustained prior to curettage, or if a large defect is present with a cortical shell so thin that fracture is inevitable if unprotected following curettage, the limb should be protected until new bone formation obliterates the defect For lesions in the femur a plaster-of Paris spica extending from the axilla to the toes on the affected side affords the best protection. After 5 or 6 weeks this may be replaced by a long leg cast extend ing from the toes to the groin When roent genograms exhibit obliteration of the cav ity a Thomas ischial weight bearing caliper is applied and weight-bearing is started Physical measures to restore joint function are instituted The limb should be protected until there is sufficient roentgenologic evi dence that fracture will not occur

Resection Giant-cell tumors of the upper end of the fibula are treated best by resec tion In performing this procedure care should be taken to remove sufficient normal bone distal to the tumor This ensures abla tion of the lesion in toto Moreover the

peroneal nerve as it winds around the head of the fibula must be freed meticulously and retracted out of danger The technic for resection of the upper end of the fibula is described on page 709

AMPUTATION Comprehension of the true nature of a genuine giant-cell tumor has greatly reduced the number of amputations to irradicate the malady Amputation of a limb is justifiable only when there is clinical and histologic evidence that the neoplasm has undergone malignant transformation following treatment by irradiation or surgery On occasion such undesirable sequelae as *infection and irradiation necrosis* may render the extremity useless, here amputation is advisable An occasional lesion may exhibit on histologic examination unequivocal evidence of malignancy in such instances primary amputation is mandatory The site of amputation depends upon the location of the malignant lesion If it involves the fibula or the upper end of the tibia amputation is performed through the supracondylar level of the femur This site provides a suitable weight bearing stump High thigh amputations are performed for malignant giant-cell tumors situated in the distal end of the femur (The technics for amputations at different levels are described in Chapter 13)

Prognosis. Prognosis of a giant-cell tumor is predicated on many factors Notably are the age of the patient the site of the tumor and the characteristics of the stromal cells In general the outlook is better in young individuals lesions of the upper extremity give a more favorable prognosis than those in the lower extremity Clinical experience discloses that the prognosis is unfavorable in lesions which tend to recur following treatment Such behavior should arouse suspicion of malignant transformation and should influence the prognosis accordingly

Jaffe s observation on the aggressiveness of giant-cell tumor based on changes in the cytologic pattern of the stromal cell provides valuable aid in prognosticating the clinical behavior of a tumor in point Also it is reasonable to believe that in the future this information will influence the choice of treatment to be employed

SOLITARY BONE CYST

Introduction This lesion is now accepted as a distinct entity possessing distinguishing clinical roentgenographic and cytologic characteristics It has a predilection for the ends of long bones, its most prevalent site being the upper end of the humerus, the femur and the tibia However *there is no unanimity of opinion relative to* the origin of this lesion this stems from the close similarity of bone cysts to giant-cell tumors

Three distinct varieties of this lesion are recognized (1) the most common form is the bone cyst found in young children in the metaphysis of long bones (on the diaphysial side of the epiphyseal plate), (2) in latent bone cysts observed in older children and adults which is located in the shaft of the bone at some distance from the epiphyseal line (an older form of the first variety which during the period of bone growth has migrated toward the middle of the shaft) and (3) that group encountered during adolescence this lesion borders on the epiphyseal disk and exhibits more acute clinical manifestation than do the other two varieties Histologically they bear close resemblance to giant-cell tumors Coley considers this lesion an intermediate form between simple *bone cyst and giant-cell tumors* whereas Geschickter considers it as a giant-cell variant of bone cyst (Fig 437)

Origin Virchow (1878) was the first to describe bone cyst this initiated much speculation concerning the origin of the lesion Numerous diversified concepts as to its source of origin have been advanced unfortunately each one lacks uncontestable evidence for acceptance

There are those who are of the opinion that the lesion results from metabolic dis

turbance (Sisk), a theory not substantiated by other workers. Other investigators have proposed that the disease is caused by intra medullary inflammation (Bloodgood, Pfeif fer) however, bacteriologic investigation has failed to provide conclusive evidence to support this theory Trauma and hemor rhage have aroused the interest of many workers who have attempted to correlate these factors with formation of bone cysts (Mouclaire and Burnier, Pommer Jenckel and Mikulicz)

More recently Geschickter and Copeland contended that a close relationship exists between the constituents of bone cysts and those of giant-cell tumor They maintain that the elements of bone cysts represent a reparative process of bony elements taking place around an area of bone destruction which soon becomes arrested the healing or reparative phase may persist for many years giving rise to the latent bone cyst Failure to collapse the bony wall of the cyst is responsible for persistence of the lesion into adult life This fact is substantiated by the knowledge that fracture of the cortical shell spontaneous or surgical usually is fol lowed by rapid healing complete oblitera tion of the cyst may occur

Age, Incidence and Site. Solitary bony cysts are encountered between the ages of 5 and 15 years the intermediate variety (Coley) or giant-cell variant (Geschickter and Copeland) are seen during adolescence while the latent inactive form is observed in older individuals in whom the lesion has a much longer history or has caused no symptoms

Approximately 50 per cent of all cases of bone cysts are located in the upper ends of the humerus and the femur the next site in order of frequency is the upper end of the tibia Males are affected more fre quently than females The highest incidence occurs between 6 and 10 years the age ranges from 3 5 to 60 years the average being 16 4 years

The pertinent distinguishing feature of active bone cysts which set them apart from giant-cell tumors is their metaphyseal location always on the diaphysial side of the epiphyseal plate This region is also the site of origin for the quiescent or latent va riety but they gradually migrate toward the mid-shaft as the bone grows.

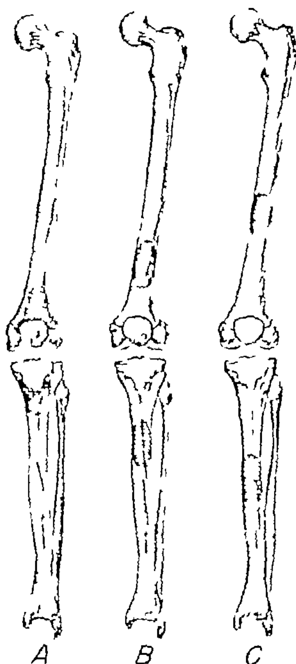


Fig 437 Types of cysts (A) Inter mediate variety between bone cyst and giant-cell tumor found during adoles cence. (B) Bone cyst appearing in child hood. (C) Latent bone cyst encountered in older children and adults.

Pathology Gross investigation discloses

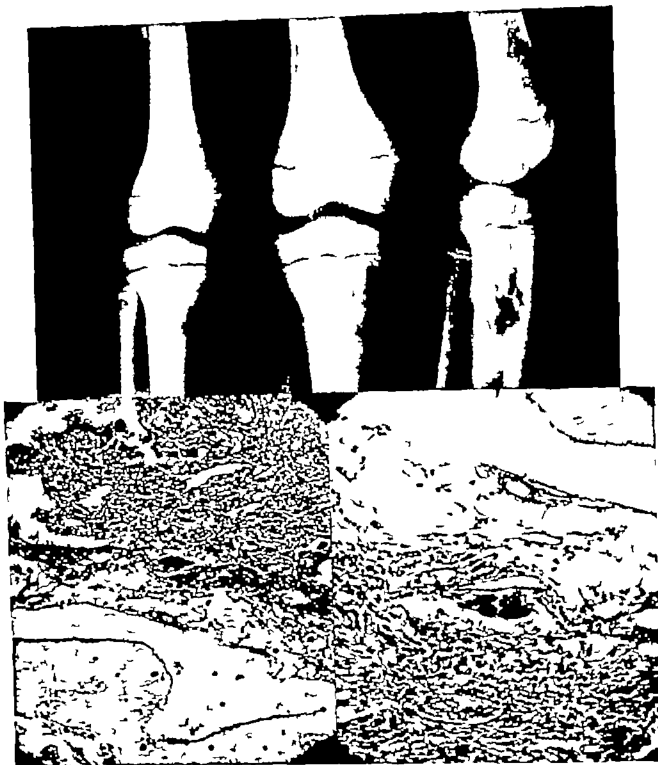


FIG 438 (*Top, left*) Bone cyst in the upper end of the tibia of a female, aged 6 Observe the radiolucent nature of the lesion and its juxta-epiphyseal location The cortex of the tibia is thin no evidence of new bone formation is discernible. (*Top, right*) The cyst was curetted and packed with bone chips and bone struts observe the coalescence of the bone chips and the partial obliteration of the cavity (*Bottom*) Cytologic pattern of material removed in this case. Note the multinucleated giant cells dispersed throughout the tissue, resembling osteitis fibrosa endothelial cells and fibroblasts are demonstrable (Photomicrographs left ×100 right ×200)

tibia are not under cover of fleshy muscle masses hence, varying degrees of swelling may be discernible. Advanced lesions in the femur, and especially in the tibia may produce a fusiform enlargement that is readily demonstrable by palpation This becomes even more apparent when the affected side is compared with the opposite side.

that the constituents comprising bone cysts vary in different lesions. The age of the patient and the duration of the lesion are responsible in part for this variation Lesions of short duration exhibit a thin enveloping bony shell Bloodgood pointed out that a bone cyst may or may not possess a connective tissue lining the contents of the cyst may consist of a cavity filled with a yellowish fluid or a solid mesh of fibrous tissue (osteitis fibrosa) occasionally numerous small cavities are encountered (multilocular cysts)

According to Coley the neoplasm is initiated by a subcortical hemorrhage followed first by localized bone destruction then granulation tissue containing osteoclasts (giant cells) fibrosis and finally cyst formation. Geschickter and Copeland describe the sequence of the process as follows first *the formation of giant-cell areas followed* by the appearance of new blood channels and hemorrhage absorption of the hemorrhage follows this results in the formation of cysts lined with connective tissue which ultimately is transformed into bone

Progression of bone cysts is usually slow its rate of growth parallels the intensity of the symptoms The implicated bone portion expands slowly as the overlying cortex becomes very thin The more acute forms exhibit no evidence of bone reaction although some condensation of the bony shell is demonstrable in the latent forms Minor *trauma may result in fracture of the weak*ened bone Generally fracture stimulates a reparative process evidenced by new bone formation. On occasion the healing following fracture is sufficient to obliterate the cyst

Microscopic investigation reveals wide variations in the cytologic pattern of bone cysts Some lesions closely resemble giant cell tumors this is particularly true of the intermediate varieties encountered during adolescence Other cysts do not differ from osteitis fibrosa. Most observers are of the opinion that the variations are different stages of the same pathologic process and *are related to giant-cell tumors* Also they maintain that the variable factors responsible for the different behaviors of bone cysts and giant-cell tumors are the age of the patient, the region of the bone affected and the response of the surrounding bone to the pathologic process. In the region of the metaphysis sufficient resistance is encountered to restrain the aggressiveness of the lesion while in the epiphyseal region less resistance is offered by the cancellous bone thereby allowing the destructive phase to progress Based on the above premise it becomes obvious that the pathologic processes in the region of the metaphysis result in bone cysts while those in the epiphyseal region result in giant-cell tumors.

Clinical Features As recorded previously not infrequently bone cysts are discovered accidentally by roentgenograms taken for reasons not related to the affected region. In a child the first indication of the presence of a bone cyst may be a fracture following a minor trauma As a rule, the disorder pursues a mild clinical course the duration of the symptoms varies from a few months to many years. However in adolescence bone cysts run a more acute clinical course the duration being under 6 months Latent cysts may date back from 20 to 40 years with an average duration of 2½ years.

Pain Generally pain is not a prominent clinical feature It may occur only after *exertion and as a rule* subsides after an interval of rest Of course with the occurrence of a pathologic fracture pain is accentuated Early in the disease when the bones in the region of the knee are affected pain is localized to affected bone *later it becomes more* diffuse Lesions in the upper end of the femur frequently project pain to the region of the knee joint Firm pressure over the lesion invariably elicits varying degrees of tenderness.

Swelling This is rarely detectable when the lesion is in the lower end of the femur however lesions in the upper end of the



Fig 438 (*Top left*) Bone cyst in the upper end of the tibia of a female, aged 6 Observe the radiolucent nature of the lesion and its juxta-epiphyseal location. The cortex of the tibia is thin, no evidence of new bone formation is discernible (*Top right*) The cyst was curetted and packed with bone chips and bone struts observe the coalescence of the bone chips and the partial obliteration of the cavity (*Bottom*) Cytologic pattern of material removed in this case Note the multinucleated giant cells dispersed throughout the tissue resembling osteitis fibrosa endothelial cells and fibroblasts are demonstrable. (Photomicrographs left ×100, right ×200)

tibia are not under cover of fleshy muscle masses hence, varying degrees of swelling may be discernible Advanced lesions in the femur, and especially in the tibia, may produce a fusiform enlargement that is readily demonstrable by palpation This becomes even more apparent when the affected side is compared with the opposite side



FIG 439 Latent bone cyst. Observe the condensation of bone surrounding the cyst. There is evidence of healing within the cyst cavity

FUNCTION In the early phases of development of the lesion little or no dysfunction may be apparent in the knee joint except some stiffness and soreness following exertion Later with progression of the lesion dysfunction may be increased but even in this group it is not an outstanding feature and may be entirely absent Coley records disability in only 2 out of 17 cases prior to fracture With the advent of a fracture disability is increased

Roentgenographic Features. The distinctive features of bone cysts are (1) a destructive lesion in the metaphysis in growing individuals (before closure of the epiphyseal line) (2) uniform expansion of the metaphyseal region of the shaft (3) a smooth thin cortical shell and (4) the occasional occurrence of irregular trabeculae throughout the bone defect.

In the early stages of development the aforementioned features of bone cysts may be absent. Roentgenographically, the lesion may appear as a radiolucent area in the metaphysis close to the epiphyseal plate (Fig 438) Lack of bone reaction is a characteristic finding in all uncomplicated bone cysts On the other hand in the advent of fracture new bone formation is readily discernible Also as noted previously some bone condensation is demonstrable around a latent cyst (Fig 439)

Diagnosis. Generally the age of the individual the location of the lesion in the metaphysis (on the diaphysial side of the epiphyseal disk), roentgenologic features and a mild clinical course are sufficient to establish a diagnosis of bone cyst. Occasionally it may be necessary to consider other lesions before the diagnosis is finally made Notably among these are giant-cell tumor benign chondroblastoma of bone and chondroma

GIANT-CELL TUMOR. This neoplasm usually is encountered in older individuals (after the age of 20 years) when the epiphyseal plate has become ossified It is situated in the epiphyseal region arising from an eccentric position and extending centrally and toward the articular cartilage

BENIGN CHONDROBLASTOMA OF BONE. This tumor usually is found in close proximity to the epiphyseal plate and tends to grow away from the epiphyseal cartilage toward the middle of the shaft Roentgenographically it discloses a fluffy mottled appearance histologic studies reveal that it consists essentially of immature cartilage

CHONDROMA. This lesion bears a close resemblance to bone cysts however it is rarely found in long bones On the other



FIG. 440 (A *Left*) Osteoid osteoma of the femur in a female aged 4 The symptoms had existed 1 year before the lesion was discovered. Note the fusiform enlargement of the affected portion of the femoral shaft and the pronounced sclerosis of the bone a nidus is not visible roentgenographically This case is of particular interest because after a block resection of the area the child was completely free of pain for a period of over 2 years. (B *Center*) Shows no evidence of recurrence of the lesion 1 year post operatively Then pain again appeared in the same leg but was localized at a lower level (C *Right*) Roentgenograms at this time disclosed a nidus with some bone sclerosis around the outer side of the distal end of the femur Histologic study proved this to be an osteoid osteoma. Naturally, this question arises Is the second lesion a new osteoid osteoma or is it a reactivation of some of the material left behind at the first operation?

and it is encountered more frequently in the bones of the knee joint than in the other long bones of the body except the humerus

Treatment. Now it is generally accepted that surgical intervention is the treatment of choice. Implantation of bone chips or longer segments of bone parallel with the long axis of the cyst ensures more rapid regeneration of bone and minimizes the possibilities of spontaneous fracture through the affected area Although pathologic fractures initiate healing which occasionally obliterates the bone cyst curettage of the cavity and reinforcement with cancellous bone chips assure more prompt healing The surgical treatment of these lesions is similar to that of giant-cell tumors

The disadvantages of irradiation are generally recognized It may damage the epiphysis or even result in premature ossification of the epiphyseal disk, thereby interfering with normal bone growth. Also the possible development of sarcoma in irradiated bone is a definite contraindication to the use of roentgen rays in cases where other forms of therapy are more effective

Long-range follow-up studies of the surgical management of bone cysts reveals that recurrence subsequent to curettage is not frequent However, a second curettage or in rare instances, even a third may be necessary to achieve a cure

Osteoid Osteoma

Although unanimity of opinion does not exist relative to the origin of osteoid osteoma this lesion is now generally recognized as a distinct clinical entity Most observers

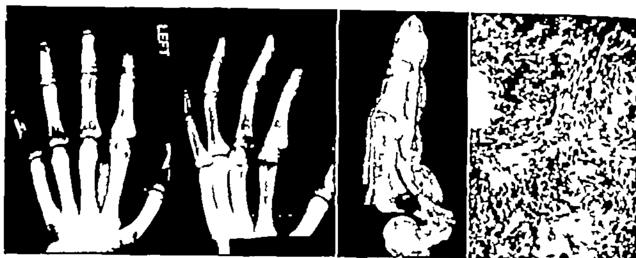


FIG 441 Osteoid osteoma of the proximal phalanx of the index finger (A *Left*) Roentgenogram of Case M G male aged 21 Observe that the index finger fails to reveal any indication of a bone lesion. Numerous views and laminographs also failed to provide any information. (B, *Center*) The amputated finger of Case M G has been sectioned in the sagittal plane observe the small discrete tumor in the proximal end of the first phalanx close to the articular cartilage (C *Right*) Tissue removed from specimen in B Observe the vascular osteoblastic connective tissue which contains many fibroblasts and osteoblasts forming osteoid spicules, and the atypical osseous tissue consistent with osteoid osteoma (Photomicrograph ×100)

are in accord with Jaffe in believing that the lesion is a benign neoplasm of bone However a few refuse to accept this concept believing that the lesion is a chronic bone infection or abscess (Brown and Ghormley Brailsford) With the accumulation of clinical and histologic data the weight of evidence is definitely against the infectious theory Lack of systemic reactions such as leukocytosis and consistent negative bacteriologic and histologic studies tends to discredit the infectious theory Also analysis of the cases reveals that trauma is not a factor in the histogenesis of the neoplasm Frequently the lesion is confused with Brodie s abscess and Garré s sclerosing osteitis The lesion has been found in all the bones of the body except the cranial bones the scapula and the clavicle

Age Sex and Incidence The highest incidence is found between the ages of 10 and 20 years it has a predilection for adolescents and young adults Sherman reported one instance in an individual 51 years old The neoplasm is more prevalent in males than in females

Site A comprehensive report made by Sherman on 158 cases of osteoid osteoma 128 of which were gathered from the literature reveals that the lesion was found in all the bones of the skeletal system except the cranial bones the scapula and the clavicle The most frequent site is the tibia and the femur It may arise in the cancellous bone near or at a distance from the articular cartilage or it may occupy an intracortical or subperiosteal position

Clinical Features. Pain is the cardinal manifestation of this disease The character of the pain may be responsible for much confusion particularly if the lesion is in the vicinity of a joint The case depicted in Figure 440 illustrates the difficulties that arise in making a diagnosis particularly if the attending physician fails to consider the possibility of an osteoid osteoma For 1 year this child complained of severe nocturnal pain which was projected to the knee joint

Roentgenographic studies of the articulation disclosed no evidence of pathology implicating the knee joint Unfortunately the films did not include the affected portion of the femur The patient was treated empirically for many months without relief, finally, roentgenographic studies were repeated, and the lesion was uncovered Generally, the pain is constant, deep and boring It is relieved by rest and accentuated by activity Nocturnal pain is a common complaint interfering with the patient's sleep Sherman pointed out that on occasion the pain may cause some dysfunction of the adjacent joint fluid being demonstrable in the joint simulating a primary arthritis

Secondary joint manifestations occurred in two of the author's cases In one case the lesion involved the distal end of the radius in the other the proximal phalanx of the left index finger

The last instance is of particular interest because the final diagnosis was not made until after ablation of the finger (Fig 441 A) The onset of the symptoms followed an injury Pain was constant and radiated to the tip of the finger the metacarpophalangeal joint was slightly swollen and painful on motion Pressure over the surfaces of the proximal phalanx invariably elicited severe tenderness The pain was more pronounced at night and required heavy sedation to allow more sleep Of interest were the vasomotor disturbances demonstrable in the entire finger the skin was thin glossy and hypersensitive The slightest pressure caused excruciating pain Repeated roentgenographic studies failed to throw any light on the causative agent All blood studies were within normal limits After consultation with the neurosurgeons the digital nerves were explored in the hope that a hidden neuroma might be uncovered Of course the procedure disclosed no pathology After all diagnostic studies were exhausted months after the onset of the symptoms amputation was decided upon to relieve the patient of the pain which was becoming progressively more intense. Sagittal section of the amputated specimen revealed a small reddish brown soft area in the proximal end of the first phalanx close to the articular cartilage A diagnosis of osteoid osteoma was made by histologic study (Fig 441 C) These cases substantiated the findings of Sherman and emphasize the clinical articular manifestations that may arise when the lesion lies in close proximity to the articular cartilage of the joint

Lesions arising in areas in which there is little overlying soft tissue, swelling and thickening of the bone may be palpable Point tenderness over the affected bony area is a constant observation Such local evidence of inflammation as redness increased local temperature and edema of the soft tissues is absent, as are other systemic manifestations of infection, such as fever and leukocytosis.

Roentgenologic Features. Except in the occasional case as described above, the final diagnosis usually is based on the distinctive roentgenographic characteristics Generally, in most instances a small round or ovoid radiolucent area surrounded by dense sclerotic bone is discernible. The central rarefield area or nidus is sometimes demonstrable only in laminographic examination However the dense sclerotic bone is always visible the extent of this perifocal sclerotic hypertrophied bone varies with the location and the duration of the lesion Lesions of long duration in the cortex or near the periosteum usually are associated with pronounced regional thickening of the shaft (Fig 440) while those situated in the spongiosa are surrounded by a circumscribed arc of bone of varying density which is seldom marked Occasionally intracortical lesions cause thickening of the entire circumference of the shaft During the early stages of development the neoplasm may fail to reveal any of the above roentgenographic features subsequent ex

aminations will uncover the true nature of the lesion. Symptoms may antedate the roentgenographic evidence by many months This is especially true in lesions arising in the bones of the feet and the hands

Pathology Macroscopic study of the neoplasm reveals the nidus to be a small cavity usually under 2 cm in its greatest dimension and containing friable reddish brown substance which bears close resemblance to granulation tissue (Fig 441 B) As a rule the nidus is located at the junction of the old cortex and the newly formed bone, or may be deeper toward the medullary cavity

Microscopic examination discloses the distinctive histologic features of this benign tumor When a well-defined nidus is present it stands out with sharp contrast from the surrounding bone Essentially it comprises a circumscribed focus of highly vascular osteoblastic connective tissue in which are found trabeculae of osteoid tissue some of which are irregularly calcified to form atypical osseous tissue Multinucleated giant cells may be dispersed throughout the tumor (Fig 441 C)

Treatment and Prognosis Block resection of the nidus with a portion of the surrounding bone has proved to be the most effective form of treatment It is interesting to note that if the lesion is removed completely pain disappears immediately and recurrence of the symptoms does not occur Such is not the case if the nidus and its contents are not totally removed as occasionally happens following inadequate block resection or curettage of the lesion With incomplete removal of the lesion the train of symptoms is not interrupted Even upon awakening from the anesthesia the patient will continue to complain of the same type of pain If the surgical defect is extensive in tubular bones especially those of the lower limb postoperative immobilization of the extremity should be insisted upon to prevent fracture through the operative site Protection of the limb is maintained until there is roentgenographic evidence of new bone formation in sufficient amount to assure against fracture. The process may be enhanced and the period of fixation shortened by filling the bone defect with bone chips or grafts Fracture of the radius occurred in one of the author s cases in which the aforementioned precautions were not observed

Sufficient data have not been accumulated to predict the outcome of untreated cases Some workers are of the opinion that spontaneous clinical arrest may occur after many years On the other hand Lichtenstein recorded one case of 7 years duration in which the nidus when eventually removed surgically exhibited no indications pointing to involution According to Sherman Phemister had under observation a case in which the diagnosis of osteoid osteoma by the present-day criterion was apparent. Surgery was refused by the patient the symptoms subsided gradually and 7 years later had disappeared completely Follow up study of this patient 24 years later disclosed by roentgenographic examination persistent thickening and sclerosis of the cortex the nidus was not discernible. Also the patient was completely free of all symptoms

What the response of osteoid osteoma would be to irradiation is not definitely known However it becomes obvious that since surgical treatment affects a rapid and lasting cure roentgen ray therapy should be reserved for those cases which are surgically inaccessible

Nonosteogenic Fibroma of Bone

In 1942 Jaffe and Lichtenstein first described this benign bone neoplasm and set forth its distinctive pathologic and histologic feature According to their premise the lesion originates from mature marrow connective tissue and does not undergo osseous metaplasia Some observers refuse to recognize the lesion as a true tumor of bone believing it to be the result of local disturbance of bone growth nevertheless it is

generally accepted as a pathologic entity *Frequently the neoplasm is confused with* monostatic fibrous dysplasia, variants of giant-cell tumors, xanthoma of bone and even osteolytic osteogenic sarcoma There are no instances on record in which *sarcomatous transformation* has occurred

Site Age and Sex. The sites of predilection are the ends of the long bones, particularly the femur, the tibia and the fibula *Usually, the lesion is observed to the end of the shaft approximately 1 to 2 inches* from the epiphyseal cartilage In the large tubular bones it tends to occupy an eccentric position lying close to the cortex and sharply demarcated from the center of the shaft by a zone of sclerotic bone *In contrast* with this in small long bones as the fibula or the ulna, it fills the entire width of the shaft, giving it the appearance of fibrous dysplasia, bone cyst, or an *osteolytic osteogenic* sarcoma

Older children and adolescents usually are affected only on rare occasions is it encountered in adults The incidence in males and females is approximately the same

Clinical Features. The cardinal symptoms are pain and swelling of the joint near the lesion, the symptoms are more pronounced in the lower extremities than in the upper Frequently, attention is focused to the implicated region by some form of trauma On the other hand fracture of the thinned cortex may be the first clinical manifestation of the lesion In the cases reported the duration of the symptoms be*fore the lesion was uncovered was brief* There is clinical evidence to believe that the lesions grow slowly and insiduously before giving rise to symptoms leading to their



FIG 442 Nonosteogenic *fibroma of the* upper end of the tibia in a male 9 years old. Note the eccentric position of the irregular lesion *It is* delineated clearly from the surrounding bone by a sharp zone of sclerotic bone. The cortex is thin *and the lesion is* multilocular This patient was cured by simple curettage of the lesion.

discovery Also, some latent lesions are disclosed accidentally by the roentgenologist.

Roentgenographic Features. Roentgenographically, the tumor exhibits distinctive features In the large limb bones it is observed at the ends of the shafts not far from the epiphyseal cartilages Its size varies considerably, but its longest dimension parallels the long axis of the shaft. It occupies an eccentric position and its inner aspect is clearly delineated by a zone of sclerotic bone, while the cortex over the peripheral portion of the bone may be thinned and even expanded In the event of a fracture the continuity of the outer cortex is broken, this is a rare finding The lesion presents an irregular area of rarefaction which may be loculated by thin bony trabeculae (Fig. 442)

Lesions in the small limb bones, such as the fibula and the ulna, also possess distinguishing characteristics Here the neoplasm occupies the entire width of the shaft which it tends to expand uniformly The overlying cortex is thin and at times may reveal a fracture. These findings bear close resemblance to bone cysts and giant-cell tumors and fibrous dysplasia from which the lesion must be differentiated Like lesions in the large bone the neoplasm is surrounded by a layer of sclerotic bone.

Pathology Grossly, regardless of its site the lesion comprises several sharply outlined but connecting foci of dense fibrous tissue varying in color from gray yellow to yellow brown The individual focus is contained in a thin layer of sclerotic bone The cortical bone adjacent to the lesion may exhibit some areas of destruction thinning and even thickening Except when a fracture has occurred the periosteum shows no significant alterations

Jaffe and Lichtenstein noted and decribed a basic cytologic pattern for nonosteogenic fibroma of bone Essentially it consists of whorled bundles of connective tissue cells However they observed considerable variation in the cellularity and the vascularity of the stroma of different tumors or even in different areas of the same tumor Some lesions exhibit varying numbers of multinuclear giant cells, and in others lipoid is demonstrable in the form of foam cells Stromal cells of some tumors are laden with granules of hemosiderin in their cytoplasm This is responsible for the brown color that some tumors exhibit moreover multinuclear giant cells are scattered through the brown tumors. It appears that there is a close relationship between the presence of hemosiderin and the appearance of multinuclear giant cells which seem to be the result of fusion of the spindle-shaped stromal cells.

On the other hand, yellowish tumors contain no hemosiderin but rather contain groups or nests of lipoid-containing foam cells which are interspersed in the stromal tissue It is believed by some workers that the foam cells arise through conversion of the spindle cells into lipophages" It is interesting to observe that the more lipophages are present in a yellowish tumor, the less hemosiderin it contains in the cytoplasm of the stromal cells and the fewer multinuclear giant cells are discernible.

Macroscopically the tumors disclose no evidence of osteogenesis the lack of new bone formation per se is an outstanding characteristic of this neoplasm

Treatment. Surgical management offers a rapid and permanent cure. In large bones the lesion may be removed by curettage or by block resection Large surgical defects may be filled with bone chips or grafts Lesions in the fibula may be eradicated readily by subperiosteal resection of the affected region of the shaft

Chondromyxoid Fibroma of Bone

In 1948 Jaffe and Lichtenstein described this rare bone tumor The author never has encountered one or at least never has recognized the lesion. According to the above workers the lesion arises from cartilage-forming connective tissue It is definitely a

benign neoplasm and may be confused with chondrosarcoma, unusual giant-cell tumor and myxosarcoma

Clinical Features. It occurs usually in individuals under 20 years of age, however, there were two cases 42 and 56 years and two between 23 and 30 years in the series of Jaffe and Lichtenstein The site of predilection appears to be in the lower extremities particularly the tibiae and the femurs. When it arises in the tibia and the femur the lesion is located in the metaphyseal region not far from the adjacent joint In these bones the lesion is usually eccentrically placed tends to expand the affected region of the shaft and erodes the overlying cortical bone.

The lesion develops slowly, and the symptoms are mild in nature awareness of the disorder is usually present some months before medical advice is sought. As a rule, the patients are cognizant of a palpable mass in the affected bone Trauma does not seem to play a part in the origin of the tumor except to make the patient aware of the lesion.

Pathology Macroscopically the neoplasm consists of a firm, solid material having a rubbery consistency and a white yellowish-white or tan color Grossly, it lacks a mucinous appearance. At the site of origin, the tumor replaces completely the osseous tissue of this region and it tends to erode and destroy the adjacent cortical bone Also it expands the implicated portion of the bone and around its periphery in part or throughout a thin zone of periosteal new bone may be discernible In areas at the periphery which are completely devoid of cortical bone, the periosteum and the periosteal connective tissue act as delimiting membranes The tumor exhibits no tendency to invade the soft tissues Finally the inner aspect of the lesion (if it does not involve the entire width of the shaft) is sharply demarcated by a zone of sclerotic bone which often is serrated or notched

Microscopically the cytologic pattern is governed by the duration of the lesion Essentially, it consists of spindle, ovoid or multipolar tumor cells loosely dispersed in a myxoid intercellular matrix. Narrow curving bands formed by more compactly arranged tumor cells divide the matrix into pseudolobules. The cells exhibit indistinct cytoplasmic borders and prominent nuclei At the periphery of the pseudolobules prominent cells with plump nuclei may be encountered also occasional multinuclear giant cells

More mature lesions disclose definite evidence of collagenization of the intercellular matrix in scattered areas, or throughout the entire tumor Occasionally some foci of calcification and ossification is noted but this is not an outstanding feature In older neoplasms the matrix exhibits in different areas, even more maturity, taking on a chondroid appearance. Here the tumor cells may actually be in lacunae, now the matrix bears close resemblance to cartilage tissue It becomes apparent that depending on the stage of maturation, the intercellular matrix may appear predominantly myxoid or chondroid in nature

Roentgenographic Features The tumor varies in size according to the first describers of this lesion, some may measure as much as 7 or 8 cm in length and 4 or 5 cm across. In the large bones, the neoplasm usually occupies an eccentric position in the metaphyseal region and shows no tendency to progress toward the end of the bone The lesion appears as a radiolucent area, usually ovoid in configuration with its long axis paralleling the long axis of the implicated bone It is expansile in nature the outer cortex may be completely eroded and replaced by a thin layer of periosteal new bone while its inner border is delimited by a sharply defined notched zone of sclerotic bone

Treatment. So far no instance of malignant transformation has been recorded in this tumor Curettage of the lesion effects a cure In cases of large tumors, the remaining

surgical defect may be filled with bone chips or grafts

Chondrosarcoma

Up to 1939 chondrosarcoma was included in the general classification of osteogenic sarcoma However the accumulated histo logic and clinical data on these tumors re vealed that they have a cartilaginous deriva tion the greater portion or even the entire tumor comprises cartilage tissue exhibiting varying degrees of differentiation and finally the neoplasms pursue a more protracted clinical course than osteogenic sarcomas These observations were responsible for a revision of the classification of primary bone tumors by the Committee of the Registry of Bone Sarcoma Accordingly these lesions were removed from the gen eral classification of osteogenic sarcoma and allocated to a separate division "Chondrosarcoma" In addition they were further subdivided into (1) primary chondroblastic sarcoma and (2) secondary chondrosarcoma

Primary Chondroblastic Sarcoma. This neoplasm is highly malignant and does not differ essentially in clinical course and prog nosis of osteolytic osteogenic sarcoma The site of predilection is the ends of the long bones its origin is from normal cartilage in the region of the epiphyseal plate It is en countered most frequently (in order of frequency) in the region of the knee the shoulder and the hip

Clinical Features This neoplasm is en countered most frequently between the ages of 10 and 25 years the highest incidence is observed in the second decade of life be tween 10 and 15 years In this respect the lesion is similar to osteogenic sarcoma. As recorded previously the most frequent site is in the region of the knee joint The cardi nal clinical characteristics are pain swelling and impaired function Frequently pain is associated with some form of trauma In the early stages of development pain is mild in nature later it is constant and accom panied by varying degrees of dysfunction in the knee joint. The duration of symptoms before medical aid is sought varies from 7 to 16 months Spontaneous fracture rarely occurs

A palpable enlargement in the affected region is usually discernible frequently varying amounts of effusion in the knee joint cavity are demonstrable Pressure over the local swelling elicits considerable tender ness As in the shoulder region tumors in the region of the knee may assume extraor dinary dimensions At first the swelling may have a doughy elastic consistency later with the advent of secondary calcification within the tumor it may become firm and hard Rapidly growing lesions may produce severe bodily reactions such as elevated temperature, loss of weight and leukocytosis

Metastases to the lungs via the blood stream occur early in the disease As yet no proved cases of metastases by way of the lymphatic system have been recorded

As a rule the serum phosphate level in these tumors is elevated and its range is indicative of the activity of the tumor In the absence of metastatic lesions the level diminishes following therapy

Roentgenographic Features During the early stages of development, lesions arising from the center of the shaft exhibit more or less irregular rounded radiolucent areas resulting from destruction of the spongiosa no new bone formation or bone condensation is demonstrable around the periphery of the lesion Both sides of the epiphyseal cartilage may be implicated and the tumor may extend toward the end of the bone in the direction of the articular surface of the femur or the tibia (Fig 443) Chon droblastic sarcomas depicting the aforemen tioned roentgenographic features may be readily misinterpreted as giant-cell tumors osteolytic osteogenic sarcomas and bone cysts With destruction of the overlying cor tical shell and involvement of the peri osteum a zone of dense bone may surround the lesion Elevation of the periosteum by

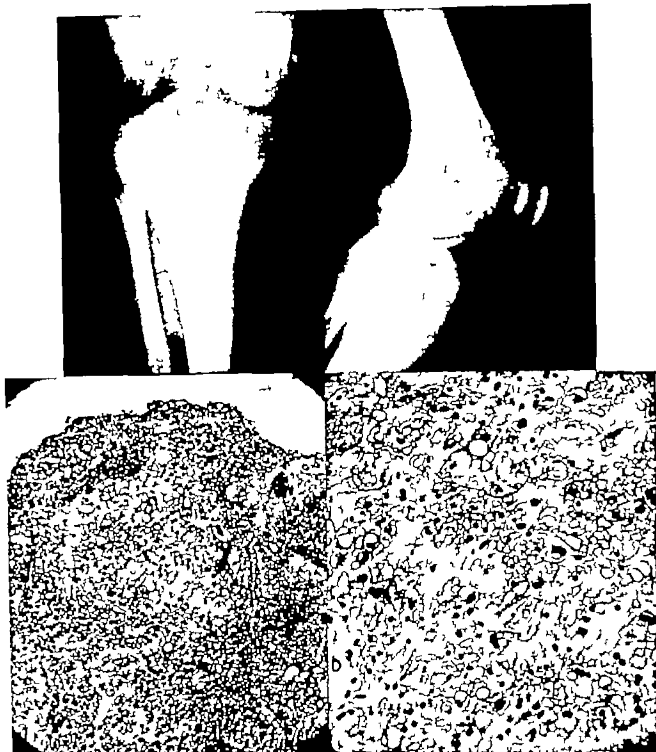


Fig. 443 Primary chondroblastic sarcoma, Case F R., male aged 26 (*Top*) Note the osteolytic nature of the lesion it involves the diaphysis and extends proximally as far as the articular cartilage No new bone formation is evident. This lesion may be interpreted erroneously as an osteolytic osteogenic sarcoma or as a giant-cell tumor (*Bottom*) Cytologic pattern of tumor tissue obtained from the tumor depicted above Observe the pleomorphic nature of the chondroblasts the marked vascularity and the paucity of stromal tissue. (Photomicrographs left ×100 right ×200)

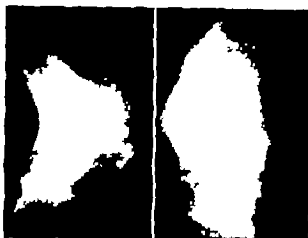


FIG 444 Chondroblastic sarcoma arising from the lower end of the femur The tissue has perforated the cortex and has invaded the soft tissues. Irregular, spotty areas of calcification are demonstrable in the surrounding soft tissues. Case G M female aged 67

the tumor tissue may stimulate the formation of new bone parallel with the shaft distal to the tumor (Codman s triangle) this is of no diagnostic significance Later stages of evolution of the tumor may depict irregular coarse trabeculae traversing the tumor giving it a multilocular configuration

PATHOLOGY Grossly the tumor comprises *a grayish white material throughout which* may be found cystic and hemorrhagic areas *of varying size and different stages of de*velopment. Its consistency varies according to the type of cartilage and the amount of calcification and ossification plus the extent of degeneration

Microscopic investigation reveals that the cytologic pattern exhibits pronounced variation in different tumors also in different areas of the same tumor Essentially the bulk of the lesion consists of cartilage cells depicting varying stages of differentiation and calcification a cartilaginous matrix and varying amounts of myxomatous tissue The *stage of differentiation of the cartilage tis*sue indicates the degree of malignancy Neoplasms exhibiting the least differentiation are the most malignant (Fig 443)

TREATMENT AND PROGNOSIS The tum not radiosensitive *however extensive* diation may influence the tumor sufficie to cause some regression and alleviatio the acute symptoms Surgery if it is formed early, offers more than any c form of therapy Early amputation of limb is indicated in all cases Resectio a primary chondroblastic sarcoma is n justified. This is not true in secon *chondrosarcomas which by histologic ex*amination are shown to be of low grade ma nancy and are situated in bones amen to resection In the region of the knee j the only region that might meet the re site is the upper end of the fibula. The p nosis is generally grave tumors in the gion of the knee joint have a far po outlook than those in the region of shoulder

Secondary Chondrosarcoma. Maligi transformation may occur in pre-exist ostensibly benign cartilaginous lesions s as chondromas and osteochondromas (si or multiple) *Although the most comi* sites for this lesion are in the bones of *shoulder and the pelvic girdle, the loca* next in order of frequency is the regio *the knee joint. Males are more comm* affected than females the highest incide *is found between the ages of 31 and* years

Characteristic features of significance the low-grade malignant nature of these mors and the tendency toward repe recurrences after conservative usually adequate surgery The presence of a p existing cartilaginous tumor is not alw demonstrable by roentgenographic or hi logic studies (Fig 445) Secondary chon sarcoma are noted for their long drawn- clinical course while primary tumors pur a more rapid and shorter course Nevert less in spite of the chronicity and the l grade malignant character of the seco ary chondrosarcomas most cases termin fatally

Clinical Features In the greater majority of the cases, patients afflicted with this disorder give a history of a swelling or mild pain in the affected region of the knee present for many months or years before the symptoms have progressed to such intensity that medical aid is sought. Frequently, a history of trauma to the part can be elicited however, its relationship to the development of malignant transformation in a benign lesion is questionable Also, the patient may or may not be aware of a pre-existing mass After many months or years, with or without cause, pain, swelling and impairment of function are manifested, increasing progressively in intensity In the series reported by Geschickter and Copeland the duration of symptoms was from 2 to 25 years this is in great contrast with a comparative series of primary chondrosarcomas in which the duration was 3 to 5 months Secondary chondrosarcoma in patients over 50 years of age may arise in bone affected with Paget s osteitis deformans.

Any pre-existing cartilaginous growth in the region of the knee (as elsewhere in the body) which is increasing in size and is associated with a progressive increase in pain and dysfunction should be regarded with suspicion and scrutinized for malignant transformation On occasion, pathologic fracture may occur late in the disease Generally, the fracture does not traverse the entire width of the bone but occurs in some portion of the involved cortex With this sequel all the above clinical manifestations are accentuated

Pathology The cytologic pattern of sec



Fig 445 Secondary chondrosarcoma arising from the shaft of the femur Observe the extensive involvement of the soft tissues and the advanced irregular calcification of the tumor Case M C., male, aged 64 The patient was cognizant of this tumor for 3 years before he sought medical aid. Although the origin of the tumor is not discernible, the duration leads one to conclude that it arises from a pre-existing cartilaginous lesion



FIG 444 Chondroblastic sarcoma arising from the lower end of the femur The tissue has perforated the cortex and has invaded the soft tissues. Irregular spotty areas of calcification are demonstrable in the surrounding soft tissues. Case G M female aged 67

the tumor tissue may stimulate the formation of new bone parallel with the shaft distal to the tumor (Codman's triangle) this is of no diagnostic significance Later stages of evolution of the tumor may depict irregular coarse trabeculae traversing the tumor giving it a multilocular configuration.

PATHOLOGY Grossly the tumor comprises a grayish white material throughout which may be found cystic and hemorrhagic areas of varying size and different stages of development. Its consistency varies according to the type of cartilage and the amount of calcification and ossification plus the extent of degeneration

Microscopic investigation reveals that the cytologic pattern exhibits pronounced variation in different tumors also in different areas of the same tumor Essentially the bulk of the lesion consists of cartilage cells depicting varying stages of differentiation and calcification a cartilaginous matrix and varying amounts of myxomatous tissue The stage of differentiation of the cartilage tissue indicates the degree of malignancy Neoplasms exhibiting the least differentiation are the most malignant (Fig 443)

TREATMENT AND PROGNOSIS The tumor is not radiosensitive however extensive irradiation may influence the tumor sufficiently to cause some regression and alleviation of the acute symptoms. Surgery if it is performed early, offers more than any other form of therapy Early amputation of the limb is indicated in all cases Resection of a primary chondroblastic sarcoma is never justified This is not true in secondary chondrosarcomas which by histologic examination are shown to be of low-grade malignancy and are situated in bones amenable to resection In the region of the knee joint the only region that might meet the requisite is the upper end of the fibula. The prognosis is generally grave tumors in the region of the knee joint have a far poorer outlook than those in the region of the shoulder

Secondary Chondrosarcoma. Malignant transformation may occur in pre-existing ostensibly benign cartilaginous lesions such as chondromas and osteochondromas (single or multiple) Although the most common sites for this lesion are in the bones of the shoulder and the pelvic girdle the location next in order of frequency is the region of the knee joint Males are more commonly affected than females the highest incidence is found between the ages of 31 and 35 years

Characteristic features of significance are the low-grade malignant nature of these tumors and the tendency toward repeated recurrences after conservative usually inadequate surgery The presence of a pre existing cartilaginous tumor is not always demonstrable by roentgenographic or histologic studies (Fig 445) Secondary chondrosarcoma are noted for their long drawn-out clinical course while primary tumors pursue a more rapid and shorter course Nevertheless in spite of the chronicity and the low grade malignant character of the secondary chondrosarcomas most cases terminate fatally

CLINICAL FEATURES In the greater majority of the cases, patients afflicted with this disorder give a history of a swelling or mild pain in the affected region of the knee present for many months or years before the symptoms have progressed to such intensity that medical aid is sought Frequently, a history of trauma to the part can be elicited, however, its relationship to the development of malignant transformation in a benign lesion is questionable Also the patient may or may not be aware of a pre-existing mass After many months or years with or without cause, pain, swelling and impairment of function are manifested, increasing progressively in intensity In the series reported by Geschickter and Copeland the duration of symptoms was from 2 to 25 years this is in great contrast with a comparative series of primary chondrosarcomas in which the duration was 3 to 5 months Secondary chondrosarcoma in patients over 50 years of age may arise in bone affected with Paget's osteitis deformans

Any pre-existing cartilaginous growth in the region of the knee (as elsewhere in the body) which is increasing in size and is associated with a progressive increase in pain and dysfunction should be regarded with suspicion and scrutinized for malignant transformation On occasion, pathologic fracture may occur late in the disease Generally the fracture does not traverse the entire width of the bone but occurs in some portion of the involved cortex With this sequel all the above clinical manifestations are accentuated

PATHOLOGY The cytologic pattern of sec

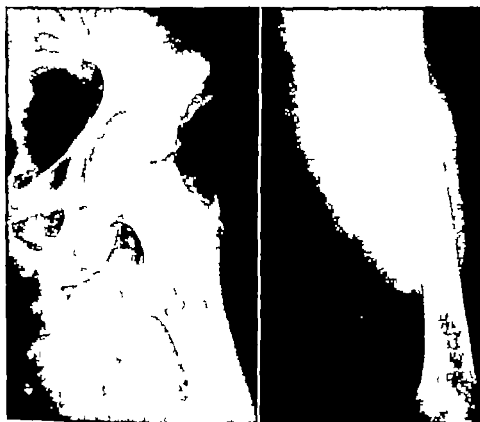


FIG 445 Secondary chondrosarcoma arising from the shaft of the femur Observe the extensive involvement of the soft tissues and the advanced irregular calcification of the tumor Case M C, male, aged 64 The patient was cognizant of this tumor for 3 years before he sought medical aid Although the origin of the tumor is not discernible, the duration leads one to conclude that it arises from a pre-existing cartilaginous lesion

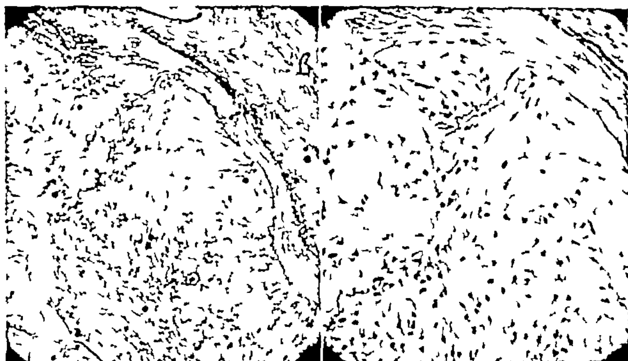


Fig 446 Cytologic pattern of secondary chondrosarcoma Observe the cellular pleomorphism, the binucleate forms of chondroblasts and the paucity of stromal tissue. (Photomicrographs left ×100 right ×200)

ondary chondrosarcomas may be difficult to evaluate and to distinguish from that of primary lesions This distinction may be facilitated if remnants of a pre-existing lesion are discernible however, such evidence may be lacking Also the presence of multiple benign skeletal lesions and (in older individuals) evidence of Paget s osteitis deformans in other bones may throw some light on the derivation of the neoplasm.

Microscopic study discloses that the *tumor consists of proliferating connective* and varying amounts of myxomatous tissues interspersed with chondral elements Cartilage cells in various stages of differentiation and showing mitotic figures indicate the malignant nature of the lesion however mitoses in great numbers is not a frequent finding Cellular pleomorphism may be evident in varying degrees Morton described the nucleate and binucleate forms and the giant cells (Fig 446) Irregular areas of calcification and ossification may be dispersed through the tumor the extent of these changes is governed in a large measure by the duration of the tumor and the rapidity of growth. Generally the tumor tissue exhibiting more cellular and undifferentiated areas is found at the periphery of the neoplasm while in its central region areas of advanced degeneration calcification and ossification are observed Spindle-shaped and stellate-shaped cartilage cells may be observed in myxomatous areas The vascularity of these tumors is a variable feature Areas of typical hyaline cartilage may be *scattered through the tumor here the* chondroblasts are ovoid and lie in lacunae

Histologically it may be impossible to distinguish a primary from a secondary chondrosarcoma Also it may be difficult to distinguish the malignant forms from the benign tumors chondroma and osteochondroma In order to evaluate the grade of malignancy of the lesion a careful search must be made of the entire neoplasm examination of isolated areas may fail to uncover its true nature

Roentgenographic Features Roentgenograms may disclose the remains of a pre

existing chondroma or osteochondroma from which arises an irregular, granular, blotchy mass Islands of calcification and ossification stand out as irregular areas of increased density particularly in the center of the tumor mass The neoplasm may cause extensive destruction of the cortex and invade the medullary canal It may extend peripherally invading the soft tissues Irregular branching shadows of varying density producing a stippled blotched appearance are characteristic roentgenographic features (Figs 444 and 445)

TREATMENT AND PROGNOSIS It is generally accepted that early radical surgery is the treatment of choice in most instances amputation of the affected limb is justified On occasion resection is permissible if the entire tumor is accessible and amenable to removal in toto Secondary chondrosarcomas of the upper end of the humerus and the scapula lend themselves to this form of treatment In 2 cases the author has performed a total scapulectomy for a secondary chondrosarcoma of the scapula Four and 2 years respectively after the operations the patients exhibit no evidence of local recurrence or metastasis Coley reported the same procedure in a patient who was living 11 years after operation For lesions in the region of the knee joint resection is a futile operation Even in regions where the tumor may be removed completely resection is justifiable only in cases which reveal low grade malignancy on careful scrutiny of the histologic structure by a competent pathologist

Clinical experience discloses that recurrences invariably follow inadequate surgery The low grade malignancy of some of these tumors is reflected in the number of recurrences which occur many years after incomplete removal In these cases the disease pursues a protracted course Death may not occur for 2 to 10 years following the recurrences The importance of definite surgery performed at the first operation cannot be overemphasized

SARCOMA OF BONE

Incidence and Age. According to Coley there is an incidence of one case of osteogenic sarcoma for every 117,000 of the population in the United States Codman s survey made in 1922 in the State of Massachusetts revealed an incidence of 1 case in 100 000 inhabitants at any one time The disease is a little more prevalent in males than females One half of the cases are encountered in the second decade and two thirds between the ages of 10 and 30 years Nevertheless the disease is not relatively uncommon in individuals between 30 and 40 years When the neoplasm occurs in patients over 50 years of age one should suspect the existence of Paget s disease of bone with sarcomatous transformation

Site The sites of predilection in order of frequency are the lower end of the femur the upper end of the tibia and the upper end of the humerus Less frequent locations are the upper end of the fibula the bones of the pelvis and the vertebral column. In tubular bones the tumors usually arise in the metaphyseal region adjacent to the epiphyseal plate occasionally they arise at a distance from the metaphyseal area

Gradation of Degree of Malignancy Most workers are in agreement that it is possible to determine the degree of malignancy of sarcoma of bone by the histologic characteristics of the cells and the tissues comprising the neoplasm Broder has evolved a classification of gradation based on the differentiation and the anaplastic features of cells Some workers hesitate to place too much faith on such a gradation while others rely heavily on the pathologist s evaluation before instituting definitive therapy for a lesion in point At the Mayo Clinic this grading of tumors has reached a high degree of proficiency The decision of the pathologist therefore plays a major role in the choice of treatment or the extent of surgery performed in that institution It becomes apparent that by such a method neoplasms of lesser malignancy may be ascer

tained and treated accordingly Tumors in this category if accessible may be treated by excision in toto with reasonable assurance that local recurrences or metastasis will not occur According to Coley, the percentage of 5 year survivals in low-grade tumors is more than twice that of higher grades combined He is of the opinion that fine subdivisions of grading into numerous groups is of no practical significance

OSTEOGENIC SARCOMA

The following distinctive characteristics are found in these neoplasms They arise in bone and are capable of producing bone They comprise 50 per cent of all bone sarcomas The nature and the amount of bone formed vary in different tumors based on this peculiarity the tumors can be placed in several different categories Generally the outlook is unfavorable and the mortality is high As noted previously in long bones the lesion originates in the metaphyseal region and tends to grow outward and downward in the shaft of the bone Invasion of the medullary canal and destruction of the cancellous and the cortical bones is a characteristic feature of the tumor Also *they may invade a portion of the epiphysis* proper When the tumor progresses as far as the articular cartilage of the femur or the tibia it meets a very effective barrier rarely is the articular cartilage penetrated In far-advanced tumors the joint cavity may be implicated by invasion of the capsule at the site of its attachment to the involved portion of the bone

As the tumor advances and the periosteum is stripped from the shaft varying amounts of new bone may be formed on the shaft distal to the tumor (Codman's triangle) With dissolution and perforation of the cortex the tumor may progress beyond the limits of the bone varying degrees of ossification may occur in the tumor tissue outside the shaft Metastasis to the lungs occurs in the early stages of the disease generally *dissemination of the tumor is* achieved via the blood stream but occasionally by the lymphatics

Pathologic fractures are not infrequent especially in rapidly growing sarcomas. It is interesting to note that this unfavorable sequel is more likely to occur in the humerus than in the femur despite the fact that the latter is a weight bearing bone (Coley and Sharp) Sclerosing sarcomas rarely cause a *fracture of the shaft*

Sclerosing Osteogenic Sarcoma. Neoplasms in this category are encountered most frequently in the bones of the lower limbs particularly the lower end of the *femur and the upper end of the tibia* Although the age ranges from 8 to 61 years the highest incidence is observed between 11 and 15 years the average age being 19.3 years Males are affected more commonly than females

Generally in the tubular bones as the femur and the tibia the tumor arises in the metaphyseal region Its clinical course is not so acute as the osteolytic form the duration of symptoms from onset to treatment being less than a year Pathologic fracture is rarely encountered in this tumor Irradiation has no curative effect on the lesion *It is radioresistant*

Lesions in the region of the knee joint are associated early with more impairment of function than those involving the upper extremity In advanced cases palpation reveals an irregular hard bony tumor in the lower end of the femur or the upper end of the tibia The massive quadriceps muscle may conceal the bony mass in the lower end of the femur nevertheless the implicated region appears fuller and more prominent than the unaffected side In the upper end of the tibia the discrepancy between the involved and the uninvolved sides is more readily discernible Pressure over the swelling elicits pain Rarely does effusion in the articular cavity reach such proportions that it is demonstrable clinically

As stated previously impairment of function occurs early in the disease generally



Fig 447 (A *Top left*) Sclerosing osteogenic sarcoma of the upper end of the tibia. Case R. F female aged 13 Observe that the pronounced increased density has obliterated the normal pattern of the bone the cortex has been perforated and the tumor extends into the soft tissues The neoplasm has not crossed the epiphyseal plate (B *Top right*) Gross specimen of the tumor depicted in A. Note that the entire upper end of the medullary cavity of the tibia contains tumor tissue also observe that the tumor has perforated the cortex and has grown to large proportions in the soft tissues. Areas of necrosis are demonstrable in the tumor (C *Bottom*) Histologic pattern of tissue removed from the tumor Note the irregular trabeculae of osteoid tissue which exhibit no definite pattern numerous malignant osteoblasts are discernible on the peripheries of the trabeculae some areas of the tumor show numerous blood channels. (Photomicrographs left ×100 right ×200)

the patient walks with a slight limp pain is intensified by activity and relieved by rest Later dysfunction is more pronounced and the knee is held in varying degrees of flexion at all times Pain at night may be severe The child R F whose knee is depicted in Figure 447 would awaken during the night with excruciating pain in the knee joint

Roentgenographically the tumor possesses some distinguishing features Irregular areas of increased density obliterating the pattern of normal bone appear in the metaphyseal region As the tumor grows outward and toward the mid-shaft of the bone the cortex is destroyed and the soft tissues are invaded now the same dense areas of tumor bone noted above appear beyond the confines of the shaft of the involved bone (Fig 448) The neoplasm rarely crosses the epiphyseal line to involve the epiphysis proper however occasionally and in advanced lesions the tumor may progress to the under surface of the articular cartilage Fine spicules of tumor bone radiating at right angles to the shaft may be observed giving the sun ray appearance This is not a constant feature and has no diagnostic significance (Fig 447 A)

The cytologic pattern is extremely variable essentially, it comprises a frankly sarcomatous stroma which forms tumor osteoid and new bone In sclerosing osteogenic sarcomas the stroma is endowed with unusual powers of osteogenesis, hence highly sclerotic bone may be discernible within the tumor The tumor cells may display atypism and pleomorphism or they may be predominantly atypical spindle-shaped cells The osteoid tissue is laid down in irregular trabeculae with no definite pattern

The peripheries of the trabeculae may be lined by numerous malignant osteoblasts Occasionally one encounters in the tumor areas of malignant cartilage exhibiting calcification and even ossification The vascularity of the tumor is another variable factor numerous vascular channels may be observed throughout the tumor

Osteolytic Osteogenic Sarcoma This form often referred to as telangiectatic sarcoma of bone and "malignant bone aneurysm" is a relatively rare bone neoplasm Diagnosis may be exceedingly difficult



Fig 448 Sclerosing osteogenic sarcoma of the lower end of the femur Case W H male aged 60 This case presents several unusual features It occurred in the late years of life and it exhibits an unusual amount of tumor bone formation

often it is confused with bone cysts giant cell tumors and metastatic carcinoma It is a highly destructive vascular lesion very malignant and carries an unfavorable outlook. This neoplasm occurs more frequently in the second decade of life but may occur in older age groups Ages range from 13 to 60 years the average being 28 5 years The highest incidence occurs between 16 and 20 years Pathologic fracture is a common sequel some series report an incidence of approximately 50 per cent

In advanced cases when the lower end of the femur or the upper end of the tibia are involved, the knee region exhibits a globular or fusiform swelling the skin, as a rule is stretched tightly over the tumor mass but it may remain freely movable the surface temperature of the affected area is increased The tumefaction may be soft and boggy Varying degrees of dysfunction at the knee are usually present

Roentgenographic studies exhibit pronounced dissolution of the bone affected As a rule the tumor does not extend beyond the articular cartilage rarely does it invade the joint cavity except in far advanced cases In these instances the tumor gains entrance to the joint by perforating the capsule at its point of attachment to the affected bone In early cases new periosteal bone formation on the shaft distal to the tumor may be demonstrable on occasion the "sun ray" pattern of new bone is present With progression of the tumor no evidence of new bone formation may be discernible Pathologic fracture is a frequent sequel

Microscopically the neoplasm comprises spindle shaped plump spindle shaped and stellate-shaped tumor cells in a loose arrangement varying amounts of osteoid matrix are demonstrable The tumor cells exhibit an extreme degree of anaplasia hyperchromatism and mitotic figures The tumor displays numerous blood channels or lacunae some of which are lined by endothelium others possess no endothelium and still others are lined by tumor cells

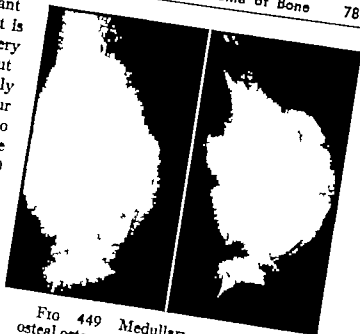


FIG 449 Medullary and subperiosteal osteogenic sarcoma in a male aged 11 Note that the tumor has invaded the medullary canal and is growing under the periosteum A well formed "Codman s triangle" is discernible at the upper end of the tumor Also the tumor has penetrated the epiphyseal plate this occurs rarely

Medullary and Subperiosteal Osteogenic Sarcoma. This is a relatively common group of osteogenic sarcomas which arise within the bone and destroy first the spongiosa and then the cortex. Tumor tissue grows and extends into the medullary canal and occupies a position under the raised periosteum.

Tumor bone is formed varying in amount and degree of differentiation. In addition reactive new bone is laid down by the periosteum distal to the tumor in an attempt to impede its progression As the tumor grows the reactive bone is destroyed but another layer is laid down distal to the new limits of the neoplasm As in other types of osteogenic sarcomas the tumor tends to grow toward the mid-shaft of the implicated bone rather than toward the epiphyseal region The epiphyseal plate appears to act as a barrier to the tumor but

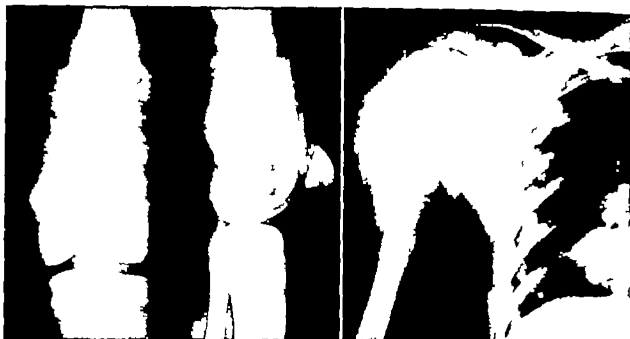


FIG 450 (*Left*) Fibrosarcoma (periosteal type) in a male aged 13 There is only minimal involvement of the shaft. This patient had similar lesions in the upper ends of both humeri (*Right*) The left humerus is shown The lesions were considered as examples of primary multiple sarcomas

in advanced cases this too is penetrated (Fig 449)

Fibrosarcoma of Bone This neoplasm arises from the fibrous connective tissue within bone or from the tissue forming the outer layers of the periosteum Primarily they comprise spindle cells whose degree of malignancy depends upon the degree of cell differentiation They never form bone Generally they are considered as the least malignant of the osteogenic sarcomas and offer the most favorable prognosis

Medullary fibrosarcomas originate in the cancellous bone near the epiphyseal cartilage As the tumor grows it invades the spongiosa eroding and perforating the cortex In some instances the raised periosteum is stimulated to the formation of reactive bone distal to the tumor Because there is a complete lack of tumor bone formation the central area of destruction is depicted in the roentgenograms as an irregular radiolucent area sometimes confused with the more malignant osteolytic sarcoma or a central chondroma

Like the medullary type fibrosarcoma originating from the outer layers of the periosteum does not form tumor bone also it exhibits little tendency to invade the adjacent normal bone (Fig 450) On occasion the bone is implicated making it difficult or impossible to determine the origin of the tumor It is generally conceded that these tumors possess a relatively low grade of malignancy also if treated early when they are amenable to surgery the survival rate of this group would be increased greatly Unfortunately in most instances treatment is initiated after metastasis has occurred

Ewing's Sarcoma

Introduction After much controversy over a period many years Ewing's tumor is now accepted as a definite clinical entity with characteristic clinical roentgenographic and histologic features Its histo-

genesis is still an unsettled question According to Ewing's original concept the neoplasm consists of angio-endothelial cells of endothelial origin Jaffe and Lichtenstein are of the opinion that it is derived from primitive marrow connective tissue Stout believes that the neoplasm is a variant of reticulum sarcoma, originating from the supporting mesenchymal tissue of the bone marrow while Oberling states that the tumor is a reticulosarcoma

In spite of its obscure and undetermined origin, many distinctive features of this bone neoplasm have been uncovered It is exceedingly radiosensitive, metastasizes to the lungs, the lymph nodes and other bones and usually terminates fatally

Incidence Age Sex, Site. Ewing's tumor is relatively common and occurs most frequently in children and young adults It is rarely encountered after 30 years of age The highest incidence is between 6 and 15 years. Males are affected more often than females, the ratio being approximately 2 to 1

The initial lesion is encountered most frequently in one of the bones comprising the pelvic or the shoulder girdle and the vertebral column Also a single lesion is often observed first in one of the long bones particularly the femur the tibia or the humerus in these bones the neoplasm has a predilection for the shaft rather than the ends of the bones.

Clinical Features Trauma appears to play no part as a causative agent in the development of the tumor Pain is the most pertinent clinical manifestation Although in the early stages it may be mild in nature its intensity increases progressively Lesions in the femur and the tibia may project pain to the knee joint and if the lesion is in close proximity to the joint an effusion in the articular cavity may be demonstrable Later in the disease pain is constant being most severe at night The knee displays varying degrees of impairment of function when the lesions implicate the lower portion of the shaft of the femur or the upper portion of the tibia

Another pertinent and constant clinical observation is the local swelling present over the affected bone Pressure over this region invariably elicits tenderness The presence of a tumefaction in the greater majority of cases is indicative of the tumor's great tendency to break through the cortex and involve the surrounding soft tissue Occasionally the skin over the tumor is tense and thinned, and the subcutaneous veins stand out prominently Fractures may occur, particularly in the tubular bones strange as it may seem, this sequel is more apt to occur in the humerus than in the other long bones

Constitutional reactions such as fever, leukocytosis and secondary anemia are common manifestations of the disease, also the sedimentation rate may be elevated These observations have been responsible, in many instances for the erroneous diagnosis of osteomyelitis. Not infrequently such cases have been operated upon and the diagnosis has not been established until after meddlesome surgery had been performed Lichtenstein makes the interesting observation that cases that exhibited the constitutional manifestations enumerated above invariably pursued a more fulminating clinical course, ending in death within a few months after admission to the hospital On the other hand those that exhibited no clinical evidence of constitutional reactions survived a year or more

Generally the disease tends to run a variable clinical course and is usually fatal Early metastases to the lungs and the lymph nodes and later to the bones is a characteristic feature of the neoplasm Bones of the skull are frequent sites for metastatic lesions Reported cases reveal that the time range between the first appearance of bone lesion and multiple bone involvement is from 2 5 months to 4 years

Roentgenographic Features. Essentially the lesion is osteolytic in nature never producing bone the new bone forma



FIG 451 Ewing s sarcoma of the femur in a female aged 27 Observe the extensive involvement of the shaft a pathologic fracture has occurred. The roentgenographic features resemble closely those of osteomyelitis. This patient was treated as a case of bone infection the diagnosis was made by histologic examination 6 months later

tion noted roentgenographically is reactive bone formed by the periosteum and the endosteal elements through stimulation of the advancing tumor Destruction or lysis of bone is the only consistent roentgenographic feature of Ewing s tumor For this reason it is often misconstrued for an infectious process or some other form of osteolytic bone malignancy (Fig 451)

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Later, the neoplasm progresses along the shaft of the affected bone and causes osteolysis of the cortex and irregular mottling and rarefaction of the medullary cavity Periosteal bone formation may produce a zone of increased density at the periphery of the tumor Reactive periosteal bone is usually more abundant in children than in adults In advanced lesions dense spicules of necrotic bone may be evident simulating an infectious process of bone

Pathology Macroscopically one notes that the tumor arises in the medullary canal It destroys and invades the cancellous bone and then the cortical bone It extends up and down the medullary canal the shaft expanding as it grows With destruction and lysis of the cortex the neoplastic tissue proliferates under the periosteum in advanced cases large amounts of tumor tissue are found in this position Marked thickening of the shaft may result from endosteal and subperiosteal bone formation Only rarely does the tumor cross the epiphyseal line Subperiosteal bone is laid down parallel with the shaft but with separation of the periosteum new bone is formed at right angles to the shaft following the course of the blood vessels (Ribbert)

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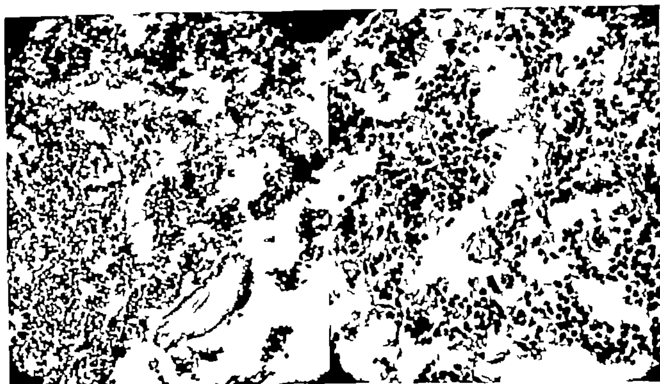


FIG 452 Ewing s sarcoma The cytologic features comprise compact areas of small polyhedral cells with scanty cytoplasm and a round hyperchromatic nucleus. Inter cellular stroma is absent (Photomicrographs left ×100 right ×200)

difficulty in identifying the tumor Areas may be observed which are heavily infil trated with polymorphonuclear leukocytes giving the appearance of an infectious proc ess. Also, microscopic interpretation of this lesion is often confused with reticulum-cell sarcoma and metastatic bone lesions from neuroblastoma of the sympathetic system Willis is of the opinion that frequently the latter is diagnosed erroneously as Ewing s sarcoma

Treatment and Prognosis. Although the tumor is exceedingly radiosensitive ir radiation alone never has effected a cure Roentgen ray therapy relieves pain and causes regression of the tumor However it does not prevent metastasis which invari ably follows regardless of the local status of the initial neoplasm. Inadequate dosages of irradiation tend to make the tumor less radiosensitive

It is generally accepted that surgical management with or without irradiation is the best form of treatment Coley states that resections should be performed more frequently in such bones as the fibula the ulna and even the scapula and the humerus He justifies his opinion by the observation that amputation offers no more hope for a cure than does resection Critical analysis of the statistics reveal that the results of amputation are far from encouraging in fact they are poor Resection if feasible holds no more hope for the patient but he is spared a mutilating operation Moderate dosages of roentgen therapy before ampu tation or resection and heavier dosages after the wound has healed is the plan of treat ment in most institutions.

On the whole prognosis is poor metas- tases and death are the usual sequelae The survival period after the initial symptoms of the disease is variable but it is rarely over 2 years

MULTIPLE MYELOMA

Introduction. It is now generally con ceded that multiple myeloma (plasma-cell myeloma) is truly an endosteal tumor It



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In the early stages of development increased density and expansion of the implicated portion of the bone may be discernible this results from endosteal and subperiosteal bone formation On occasion subperiosteal bone is laid down parallel with the long axis of the shaft of the bone giving the onion-peel effect often described as characteristic of Ewing's sarcoma. It must be emphasized that the laminated periosteal new bone is only rarely encountered in Ewing's tumor and that when present, its significance must not be overestimated as indicative of Ewing's tumor because there is the possibility that other lesions may produce the same bone pattern

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The cytologic pattern comprises compact areas of small polyhedral cells with a round hyperchromatic nucleus and scanty cytoplasm with distinct but irregular outline (Fig 452) No interlacing stroma is present. This pattern may be so altered by secondary changes as degeneration and necrosis of the tumor cells and by hemorrhage and reparative reaction that one finds great

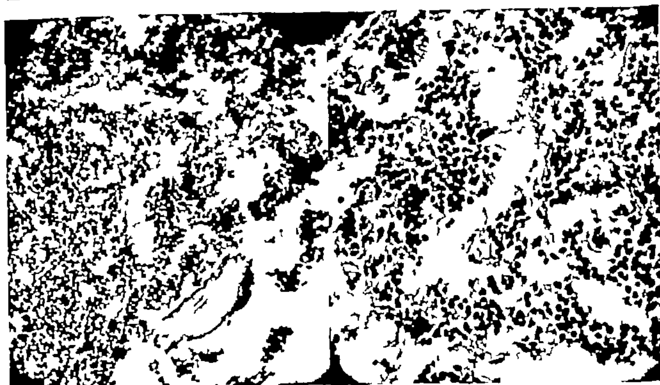


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MULTIPLE MYELOMA

Introduction It is now generally con ceded that multiple myeloma (plasma-cell myeloma) is truly an endosteal tumor It

arises from the blood forming elements of the bone marrow and it is multifocal in origin The disease is extremely malignant and although pain may be controlled some times and life may be prolonged by irradia tion the ultimate outcome is invariably fatal Some authorities are of the opinion that multiple myeloma may be subdivided into 4 categories plasma-cell myeloma is the most common (94% of all myelomas) the others in order of frequency are myelocytoma lymphocytoma and erythroblas toma. Other observers refuse to believe that these tumors are distinct clinical entities but contend that the disease is of unitary cell type the variations in cytologic pat terns reflecting stages of maturation of the basic tumor cell (Lichtenstein) In regard to the histogenesis of multiple myeloma Wallgren Wood Wintrobe and others be lieve that the tumor comprises distinctive cells of myeloid formation or hematic origin

The etiologic factor responsible for the myelomas is obscure Some investigators contend that they are not true primary bone tumors but diseases of the lymphoid system (Meyerling) or of the lymphatic hemopoi etic system (Lubarsch) This tumor may be confused with several entities metastatic carcinoma offering the greatest difficulty Giant-cell tumor must be considered in the differential diagnosis when roentgenographic examination in the early stages exhibits only a single lesion At times Ewing's sarcoma must be considered in arriving at a diag nosis However the age of the patient (usu ally over 40 years) the presence of Bence Jones protein in the urine (over 50% of the cases) and the histologic examination of the bone marrow (obtained by sternal or iliac puncture or open biopsy) suffice to establish the diagnosis in the majority of the cases In many instances final diagnosis defies the most exacting scrutiny of the malady and the diagnosis must be made by exclusion of other lesions In this process all diagnostic aids must be employed and evaluated bio-chemical data may add valuable informa tion, especially the serum protein values Hypercalcemia is observed in over 50 per cent of the cases this reflects the lytic re sorption in the osseous system often it is associated with renal insufficiency This is not diagnostic of multiple myeloma but together with other information may fortify a tentative diagnosis particularly when it is a concomitant finding with hyperprotein emia or Bence Jones proteinuria

Serum phosphatase levels are always within normal limits except for slight ele vations in the event of a pathologic fracture Hyperproteinemia specifically hyperglob-ulinemia is a pertinent and concomitant feature of some cases of multiple myeloma serum albumin values are usually normal or even diminished Also increased values of uric acid in the blood may occur in this disease reflecting breakdown of the nucleo-proteins contained in the tumor cells

Incidence Age Sex. This disorder is more common than is generally realized Although improved diagnostic aids such as sternal and iliac puncture facilitate the di agnosis many cases are encountered in which these measures fail to provide the necessary information Of course open biopsy in such cases must be performed if the final diagnosis is to be established The tumor is rarely observed in patients under 35 years of age there are some cases in the literature under 30 years the highest inci dence is between 56 and 60 years It is gen erally conceded that multiple myeloma oc curs more frequently in males than in females however there is considerable discrepancy in the exact ratio in different series of cases it varies from 1 1 to 3 1

The bones that most frequently disclose clinical and roentgenographic manifesta tions of the disease are in order of fre quency the vertebrae the ribs the pelvis the femur and the humerus

Clinical Features. The disease may be ushered in by bizarre clinical manifesta tions Vague pain in the back the abdomen and the chest may be the only early com

plaints of the disorder Because of the progressive anemia weakness, malaise and loss of weight may be associated symptoms pain, which at first may be mild may increase progressively in intensity and, as a rule, is accentuated by activity It may be intermittent in fact, periods of remission which may last for months with or without treatment are common Rest generally gives relief, nocturnal pain is not a distinctive feature. While the remission period is usually under a year, cases have been recorded in which the remission lasted for 3 to 5 years

Occasionally, pathologic fracture may be the first evidence of the neoplasm in other instances the presence of a palpable mass in the affected bones may be the initiating complaint Rarely it is precipitated suddenly by acute radicular pain or even varying degrees of paraplegia resulting from collapse of one or more vertebral bodies Fractures are encountered most frequently in the ribs they are also common sequelae in the femur and the humerus The incidence of pathologic fracture has been estimated by some as high as 50 per cent of all cases of myeloma Multiple fractures are not uncommon In widespread skeletal involvement small semifluctuant tender tumors may be palpable in the ribs the sternum or the clavicle and the shafts of the long bones may exhibit uniform distention On the other hand autopsy specimens may reveal widespread dissemination of the tumor while no outward clinical or roentgenographic manifestations were discernible in the patient prior to death

As recorded previously systematic reactions through involvement of the blood forming elements and the viscera may give rise to fever malaise and loss of weight Bence-Jones bodies are found in over 50 per cent of the cases these proteins are not pathognomonic of myelomas being found also in leukemia carcinoma with skeletal metastases multiple sarcoma of bone (Seegelken Gilmore) polyfibrocystic disease (Grooves), comminuted fracture (Campbell and Horsfall) and senile osteomalacia (Rascke) Also it was pointed out that extensive destruction of the hemopoietic elements results in varying degrees of secondary anemia, and that serum protein values may be above normal limits in many cases This does not apply to serum albumin which is usually within normal limits or even diminished

The disease pursues a variable course usually it lasts under 2 years and terminates in death

Pathology Gross examination of multiple myeloma reveals marked variation in the affected bones In general, the tumor crises from multiple foci in the cancellous pace and the medula and comprises a soft gelatinous substance varying in color (gray brown or red), depending upon its vascularity In the spongiosa the points or origin grow, expand and cause resorption of the surrounding bone trabeculae and become confluent The cortex may be slowly absorbed and thinned the periosteum may be distended Characteristic of this tumor there is no reactive bone formation In some instances there may be no gross involvement of the cortex and the bony trabeculae show only minimal implication However the distinctive whitish or gray gelatinous tumor tissue replaces or infiltrates the marrow Such bones will exhibit roentgenographically diffuse porosity but not the punched-out appearance believed to be characteristic of myelomatous bones In other instances the cortex shows advanced thinning but has not lost its continuity while in other cases the tumor produces multiple areas of lysis in the cortex distends and even perforates the cortex to invade the surrounding soft tissues The latter group of cases gives rise to the features often associated with multiple myeloma namely the presence of discrete, punched-out radiolucent areas of varying size Moreover such bones particularly the long tubular bones (femur and humerus)

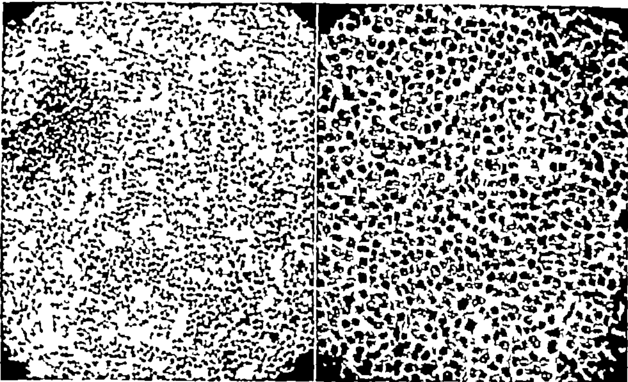


FIG 453 Myeloma. The tumor cells tend to be round and possess a stippled nucleus *which is placed eccentrically and is globular in configuration (Photomicrographs left* ×100 right ×200)

are frequent sites of fracture One must bear in mind that punched-out rarefied areas in the calvarium and other bones of the skeleton may occur at times in carcinomatosis

Histologic examination reveals a fairly constant cytologic pattern comprising groups of compact cells without intercellular material or stroma. Lichtenstein describes two subdivisions of this pattern one in which the tumor cells are quite uniform and predominantly small and have a superficial resemblance to plasma cells The tumor cell is roundish and has a stippled nucleus substantially filling the cell The darkish chromatic particles spotting the *nucleus are dispersed centrally as well as* peripherally The second group exhibits a cytologic picture which tends to be dominated by cells larger than those resembling plasma cells but may be a rather variegated one " Tumor cells of this group are larger than the myeloblast and possess abundant cytoplasm they have a large round oval or even uniform pale stippled nucleus" (Fig 453)

Roentgenographic Features The appearance of myelomatous bones in roentgenograms is governed by the degree and the manner in which the pathologic process involves the bones As recorded previously tumors in which the cortex is only slightly thinned and the bone trabeculae are still numerous exhibit roentgenographically diffuse porosity of the implicated bones. More advanced lesions but in which the cortex is still intact may give a spotty or mottled appearance while in far-advanced lesions with numerous foci of osteolysis and massive *destruction of the cortex* many punched-out radiolucent areas are discernible

Characteristic of the lesion is its osteolytic tendencies hence it may simulate giant-cell tumors osteolytic sarcomas and osteolytic metastatic carcinomatous lesions Fractures of the bone through the affected

area may occur, in these cases evidence of bone healing even if present is not marked

Prognosis and Treatment. Prognosis is always poor. Moderate dosages of irradiation can alleviate pain and induce remissions. Surgery has nothing to offer except to obtain material for a biopsy. Treatment is entirely expectant in nature. Such drugs as Stilbamidine and Pentamidine have failed to influence the course of the disease. Radioactive phosphorus in some cases may alleviate the symptoms but does not alter the progress or the outcome of the disease. In the event of fracture in the long bones the author has employed the use of intramedullary nails. This obviates the use of cumbersome casts, splints or traction apparatus. The method is particularly justifiable in debilitated patients.

Solitary Plasma Cell Myeloma

Single myelomatous lesions have been reported in the literature. The series reported by Pasternack and Waugh (30 cases from the literature and one of their own) included 7 cases which were alive from 4 to 10 years and 6 from 7 to 10 years later. In this regard the author has one case under observation which exhibited a myelomatous lesion of one of the lumbar vertebrae. The diagnosis was established by histologic examination of material obtained by open biopsy. This patient is alive 2½ years since the diagnosis was made; as yet no evidence of multiple foci is demonstrable. All symptoms were alleviated by irradiation. In spite of these reports one must be aware of the variability of the clinical course which multiple myeloma pursues and it is feasible to assume that ultimately multiple foci will develop.

It becomes apparent that a solitary lesion may offer considerable diagnostic difficulties. Its osteolytic and expansive nature may readily confuse it with giant-cell tumor and some varieties of metastatic carcinomatous lesions.

In general single lesions have a more favorable outlook. However, when considering the prognosis of a solitary myeloma, one should know that the osseous lesion is only one manifestation of a generalized affection of the hemopoietic system.

METASTATIC CARCINOMA

Greater interest in skeletal metastases from carcinoma reveals that its incidence is higher than is generally realized. It is obvious that the true incidence is difficult to determine. According to some observers approximately 50 per cent of breast, renal, prostate and bronchiogenic carcinomas metastasize to bone and that 25 per cent exhibit clinical evidence of bone involvement before death. It is generally known that carcinoma of certain viscera is more prone than others to metastasize to bone. Breast lesions frequently affect bone, while carcinomas arising in the prostate do so less frequently, malignancies of the bladder, the cervix, the uterus and the gastro-intestinal tract rarely show this tendency. In 1922 Kauffman noted on postmortem examination that roughly two thirds of all breast cancers and one half of all prostatic malignancies disclosed skeletal metastases. Secondary bone involvement may be the first clinical manifestation of cancer elsewhere. Not infrequently the primary lesion never may be uncovered even at autopsy.

Types of Metastatic Bone Lesions. Secondary metastatic lesions in bone are most often multiple; however occasionally single lesions are encountered. If single lesions are followed for sufficient time almost always multiple involvement will be demonstrable ultimately. According to some workers single lesions occur in 25 per cent of breast cancers and are observed more frequently in renal cancers. Although any bone in the body may be affected secondarily by any of the recognized forms of cancer, in general certain cancers show a predilection for specific regions. Thyroid and renal cancers most frequently metastasize to the long

bones of the extremities particularly the humerus and the femur breast and prostatic tumors metastasize to the spine and the pelvis

Metastatic foci in bone may be either osteoblastic or osteolytic in nature As a rule cancer cells are deposited in the spongiosa of the ends of long bones and in the region of the nutrient artery In response to the stimulus provided by the tumor cells varying amounts of reactive new bone formation from the periosteum and endosteal elements occur Cancers capable of such a response are referred to as osteoblastic tumors. The involved bone areas exhibit irregular areas of increased density and irregular thickening of the cortex. In addition they may show periosteal new bone *above and below the lesion On the other* hand the tumor may be purely a destructive lesion stimulating no reactive new bone formation Starting from a central focus it first destroys the spongiosa then destroys the cortex expands the shaft and perforates the periosteum. Tumors manifesting these characteristics comprise the osteolytic group They are considered as growing more rapidly attaining greater dimensions than osteoblastic tumors and being associated *more frequently* with pathologic fractures Metastatic tumors of the prostate are most often osteoblastic However some prostate cancers may be osteolytic others may exhibit both characteristics Although most breast cancers are osteolytic a large number exhibit osteoblastic tendencies Renal and thyroid cancers generally give rise to osteolytic metastatic lesions

In any discussion of metastatic lesions consideration should be given to Ewing's tumor and neuroblastoma of adrenal or sympathetic origin As noted previously these tumors also are sources of metastatic skeletal foci essentially they are osteolytic in nature especially in the tubular bones While the age period in which they occur and their cytologic features usually distinguish them readily from metastatic carcinoma it may be exceedingly difficult to differentiate one from the other

Pathologic Fractures. Fracture may be the first indication of the disease and it is not an uncommon sequel When it occurs particularly in the long bones as the femur and the tibia management of the patient becomes greatly complicated This undesirable complication may occur as the result of trivial trauma Metastatic carcinoma and multiple myeloma are the most frequent etiologic factors responsible for pathologic fractures in patients past 35 years of age The incidence is unusually high in metastatic renal carcinoma Some workers report an incidence as high as 45 5 per cent Pathologic fractures are rarely concomitant lesions *with prostatic cancers most metastatic* lesions are characterized by new reactive bone formation and are less prone to sustain fractures.

Fixation of fracture of the long bones by intramedullary pinning is a valuable method and facilitates the management of the patients alleviates pain and does not interfere with other forms of therapy

Spontaneous healing occurs occasionally however the amount of new bone is usually small and defective and refracture is the usual sequel In some cases roentgen ray therapy undoubtedly destroys the tumor cells or inhibits their activity sufficiently to allow healing Endocrine therapy and castration have been known to produce rapid bone regeneration and tumor regression in many instances of breast and prostatic tumors.

Roentgenographic Features Multiple skeletal lesions in an individual past 35 years are usually indicative of metastatic carcinoma or multiple myeloma The latter lesion may be portrayed roentgenographically as diffuse porosity of the affected bones or irregular mottling or in advanced cases as multiple discrete punched-out *radiolucent areas without* evidence of new bone formation Occasionally single mye

lomatous lesions are encountered, In the long bones as the femur, the humerus and the tibia, the neoplasm may cause considerable expansion of the shaft, resembling osteolytic metastatic carcinoma Diagnosis can be definitely established by histologic study of bone marrow obtained by sternal or iliac puncture or by study of the local tumor tissue obtained by open biopsy

Osteolytic solitary metastatic carcinoma lesions implicating the ends of long bones especially of renal or thyroid origin may be confused with osteolytic osteogenic sarcoma malignant giant-cell tumors or a latent bone cyst Osteoblastic lesions particularly those of prostatic cancer, may resemble closely osteoblastic osteogenic sarcoma. It becomes apparent that histologic study of the tumor tissue is essential to establish a correct diagnosis Blood studies revealing an elevated acid phosphatase level point to prostatic cancer

MYOSITIS OSSIFICANS CIRCUMSCRIPTA

Introduction. Single or repeated trauma may give rise to this variety of myositis ossificans The muscles most frequently affected are the quadriceps femoris and the brachialis anticus. It is common knowledge that this lesion may be mistaken for periosteal osteogenic sarcoma and treated by radical surgery, patients have lost limbs because of this erroneous diagnosis In the light of this information the author deems as essential a discussion of the myositis ossificans in a chapter dealing with bone neoplasms

Myositis ossificans (especially in the early



FIG 454 More common form of myositis ossificans Case J J male aged 29 This lesion followed a direct blow to the thigh. The roentgenograms depict the character of the lesion 8 weeks later At the end of 4 months the mass was removed without recurrence

stages) may simulate osteogenic sarcoma so closely in some instances that both the surgeon and the pathologist may not be able to arrive at a correct diagnosis in spite of all the clinical roentgenographic and histologic data before them Cases are on record, however in which sarcomatous transformation occurred in areas of myositis ossificans many years after the initial trauma Pack and Braund recorded 2 cases in which both patients died of pulmonary metastasis Shipley reported 4 cases Geschickter and Copeland 2 Coley observed 1 unquestionable case

Age Sex and Site. The quadriceps femoris the brachialis anticus and less frequently the deltoid muscle constituted the sites of predilection. It is rarely encountered in the very young or very old The highest incidence is observed between 15 and 20 years but is fairly common up to 40 The highest incidence apparently parallels the period of life in which most strenuous bodily activity occurs. Injuries sustained in football and soccer are frequently the inciting traumas. Males are affected more commonly than females

Clinical Features. Invariably there is a history of severe direct trauma to the affected part followed by tumefaction of a localized area in the quadriceps femoris muscle At first the mass is tender but not



Fig. 455 Unusual form of myositis ossificans with malignant changes in a male aged 32 following severe trauma to the lower leg when kicked by a horse This lesion was subjected injudiciously to 3 attempts to irradicate the lesion surgically recurrences occurred after each procedure Finally a biopsy was done approximately 10 months after the injury and malignant changes were discernible consistent with osteogenic sarcoma. These changes did not exist in the tissue obtained at the previous operation

prominent Later it slowly increases in size and acquires a hard bony consistency At this stage, pain is not a significant feature and recession of the tumor may occur It rarely disappears completely

Roentgenographic Features (Figs 454 and 455) Roentgenograms taken immediately following the injury fail to reveal any significant findings However, within 2 to 4 weeks evidence of calcification in the muscle is demonstrable If a subperiosteal hemorrhage is present it may be visible along the shaft of the femur According to Ferguson trauma to the soft tissues is responsible for stagnation of body fluids and calcification at first diffuse and amorphous later, it is more sharply defined dense and discrete If subjected to functional stresses the deposit assumes an osseous pattern Hence in myositis ossificans traumatica of the quadriceps femoris muscle the calcareous mass is distributed axially" and extends along the muscle fibers parallel with the shaft of the femur It becomes more sharply defined as an osseous texture forms As a rule, in old cases the osseous structure is well laminated regular in outline and is apart from the shaft of the femur lying entirely within the quadriceps femoris muscle Less frequently it may be attached to the bone for varying distances, and its outline may be irregular and fuzzy The latter cases may cause considerable concern on arriving at a correct diagnosis

During the early stages of evolution the process may challenge the most experienced workers but late cases rarely present difficulty especially in the light of a severe injury When in doubt a period of watchful waiting is justifiable before any therapy is instituted Repeated roentgenograms at frequent intervals will reveal the true nature of the disease in 3 to 6 weeks which, together with the features of the clinical course pursued within this period will aid in establishing the diagnosis.

Treatment. No treatment except rest to the part is indicated in questionable cases Surgical intervention in the early stages of the disease is contraindicated, since the entire process may be stimulated to renewed activity and tumor recurrences Excision of the mass may be performed late in the disease when all evidence of activity has subsided In doubtful cases open biopsy is justifiable

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Bibliographic Index

Subject Index